A STUDY OF VARIABILITY IN *MACADAMIA INTEGRIFOLIA* VAR. 'KEAUHOU' AT SEVERAL LOCATIONS IN HAWAII

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ABSTRACT

An experiment was designed and carried out in 1968 to study variability of nut characters in Macadamia integrifolia Maiden and Betche var. 'Keauhou', the most widely cultivated clone in Hawaii. Samples of 50 nuts each were taken at random from 2 trees at each of 21 locations on three harvest dates. Data were taken on nut weight, kernel weight, percent kernel recovery, percent stink bug injury, percent of grades 1, 2 and 3 kernels, shell length and width, and shell thickness at the base and side. These data were processed on an IBM model 360/65 computer located on the Manoa campus of the University of Hawaii.

All nut characters proved variable between locations sampled and most showed interactions between locations and harvest dates. Shell thickness, grade 2 kernels and kernel recovery varied with harvest dates, but these effects were less pronounced than locational effects and, with the exception of grade 2 kernels, showed significant interaction with locations.

Based on sample means, nut weight varied from 5.6 to 8.9 grams, and kernel weight from 1.4 to 3.5 grams, with kernel recovery ranging from 24.0 to 46.5%. Stink bug injury occurred at 12 locations and ranged from 2 to 42%. Grade 1 kernels varied from 41 to 100% while grades 2 and 3 ranged from 0 to 49% and 0 to 47% respectively. Shell width and shell length were approximately equal with a correlation of 0.943 indicating that nuts of this variety are essentially round.

Growth was divided into phenological stages corresponding to periods of pre-flowering, endosperm development, and oil formation. Average temperature and total rainfall for the phenological stages were computed from monthly weather data. Simple linear correlations between nut characters and pheno-meteorological variables showed an influence of temperature in determining nut quality and of rainfall in determining nut size.

Stepwise multiple regression analysis revealed that age of tree was the most important single factor influencing kernel weight, kernel recovery and shell thickness. Kernel weight and kernel recovery increased and shell thickness decreased with increasing age of tree. Nut size as measured by shell length, shell width, and nut weight, was influenced most by rainfall during the pre-flowering period. In each case the effect was negative.

Percent of grade 1 kernels increased and percent of grade 2 kernels decreased as average temperature increased. Temperature during the period of endosperm development had the greatest effect on grade 1 kernels and temperature during the period of oil formation had the greatest affect on grade 2 kernels. The most important factor affecting grade 3 kernels was harvest dates. As the harvest progressed toward the end of the season, percent of grade 3 kernels decreased.

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INTRODUCTION

The cultivated species of Macadamia, M. integrifolia Maiden and Betche and M. tetraphylla L. Johnson are in the ternifolia group in the family Proteaceae. Both species are native to the eastern coastal rain forest areas of Northern New South Wales and Southern Queensland (Storey 1959).

Ferdinand von Mueller, Royal botanist at Melbourne, established the genus Macadamia in 1858, naming it in honor of Dr. John Macadam, Secretary of the Philosophical Institute of Victoria. He described M. ternifolia as the type species (Storey 1959).

For a variety of reasons including the requirements of a large-scale processing industry M. integrifolia has been utilized to the virtual exclusion of M. tetraphylla in Hawaii (Storey 1957). No named varieties of M. tetraphylla or hybrids between the two species are planted commercially in Hawaii.

The first commercial macadamia orchard in Hawaii was started by E. S. Van Tassel in 1922 on the slopes of Mt. Tantalus (Moltzau 1968). This was the beginning of the "Nutridge" orchard from which six of the eight named varieties in Hawaii originated (Storey 1963).

In 1927, Moltzau made the first successful grafts of Macadamia, using a broken branch that had been hanging on the tree for several weeks as his source of scion-wood. Ten years elapsed before the full implication of the broken branch (natural girdling)was realized (Moltzau 1938). In this way, one of the largest obstacles to commercial macadamia production was overcome (Storey 1968).

The so-called nut of M. integrifolia is botanically a seed and the fruit is a follicle (Hartung and Storey 1939). The species is highly heterozygous and varieties are maintained as vegetatively propagated clones. As long as vegetative propagation of macadamia was relatively unsuccessful not much was accomplished in searching for superior trees although some selections were made as early as 1932 (Pope 1933). With the discovery that increasing the carbohydrate content of the scion-wood by girdling made macadamia relatively easy to graft, an intensive search began for superior trees.

Beaumont and Moltzau began screening seedlings in 1936 and the first test orchards were planted in 1938. In 1948, Storey released five horticultural varieties of macadamia, including 'Keauhou', the results of screening some 60,000 seedlings (Storey 1948). In 1952, two additional selections were named and described by Hamilton, Storey and Fukunaga (1952). 'Keaau' the most recent of the Hawaiian selections was released in 1966 by Hamilton and Ooka (1966).

Ripperton, Moltzau and Edwards (1938) studied nut and kernel characteristics including indirect methods for their determination; and variation encountered at different seasons and locations. This classic work, fundamental to macadamia selection standards both present and past, is still relevant.

In 1931 a processing plant was built in Honolulu to produce roasted, vacuum packed macadamia nuts (Storey 1948). It soon became apparent that of the two cultivated species, M. tetraphylla (the "rough-shell" macadamia) was generally preferred when eaten fresh, while M. integrifolia (the "smooth-shell" macadamia) was superior as a cooked product (Ripperton et al 1938).

Although Moltzau and Ripperton included both species in their studies, the trend was decidedly in favor of the smooth-shell macadamia as a processed product (Moltzau and Ripperton 1939). Poor keeping quality of macadamia nuts at room temperature and difficulty in cracking the shells without special equipment, has discouraged the use of macadamia nuts as a fresh product.

From the 25 acre seedling orchard planted by Van Tassel in 1922 the industry grew slowly until after World War II, primarily through the pioneering efforts of the Honokaa Sugar Company and the Hawaiian Macadamia Nut Company (Moltzau 1968 and Thevenin 1947). There were approximately 1,000 acres planted to macadamia in 1948 (Elliott 1949) when Storey released the first improved varieties. Since then, acreage planted to macadamia has increased steadily, reaching a planted acreage of 8,520 acreas in 1968 with 3,680 bearing acres producing a crop valued at 2.3 million dollars (Hawaii Dept. Agr. 1969).

Most of the pioneering research work in macadamia has been done in Hawaii. Cultivation, processing, packaging and marketing procedures are well understood and superior clones have replaced low-yielding seedling trees which produced low quality, variable nuts. Since Hawaii enjoys a virtual monopoly in the processed macadamia nut field, there seems little reason to believe that the past trend of expanding macadamia acreage will not continue.

Establishment of a macadamia orchard requires an accumulated investment of over $2,300 per acre for the six years prior to the first harvest (Keeler and Fukunaga 1968). Whether or not the investment will be profitable depends largely on yield and quality of the crop.

Considerable differences in quality have been found to exist in macadamia clones planted in different locations in Hawaii (Hamilton, Mouat and Cameron 1964). These may be due to differences in cultural practices or to climatic or edaphic factors. Whatever the cause, income to growers could certainly be affected.

Growers planting new macadamia orchards would prefer to plant a given variety in a location where the full potential of yield and quality could be realized. Established growers would like, insofar as possible, to control factors which reduce yield and quality. Researchers, applying special treatments to experimental trees, should be aware of the variability due solely to the trees and environment in order to plan experiments efficiently.

The present study was undertaken to study variation within a single clone at different harvest dates and different locations within the State.

REVIEW OF LITERATURE

A. Selection Standards

Macadamia selection standards for nut characters can be logically divided into two groups: 1) those dealing with size and 2) those dealing with quality. Size is important from the standpoint of mechanical sorting, cracking the nuts, and time required to cook the kernels. Quality is the combination of flavor, texture, odor and color which makes the product appealing to the consumer. Both flavor and texture are highly correlated with oil content of the kernel (Storey 1960). Oil content is highly correlated with specific gravity of the kernel (Moltzau and Ripperton 1939).

1. Size and shape characteristics

a) Shell diameter

Generally diameter is measured in two different planes to estimate roundness. Length is measured from the micropyle to the funicular end, and width is measured across the plane of the suture at the center of the suture line (Leverington 1962). Nuts having diameters less than 5/8 inch are not considered usable from the standpoint of cracking and kernel size (Moltzau and Ripperton 1939). Round nuts are best for mechanical handling and cracking. Oval and elliptical nuts sometimes jam the jaws of mechanical crackers (Leverington 1962). Leverington (1962) considered 3/4 inch the minimum acceptable diameter for nuts.

b) Shell thickness

Shell thickness is measured at the base or funicular end and on the side halfway between the base and apex of the shell (Leverington 1962). Storey (1955) reported that uniformly fairly thin shelled nuts were best for machine cracking, but Leverington (1962) found thick or medium thick shelled nuts preferable in this respect. Storey worked entirely with *M. integrifolia* while Leverington evaluated both cultivated species. The fact that *M. tetraphylla* nuts often have thinner shells than those of *M. integrifolia* may account for this seeming contradiction.

c) Size of kernel

Storey (1960) suggested that trees whose sample kernel weight averages less than 2.0 grams should be eliminated from further consideration.

d) Kernel recovery

Measured as a percentage of kernel weight to total nut weight, the minimum acceptable kernel recovery has been arbitrarily set at 33.0 percent (Storey 1960).

2. Quality characteristics

a) Oil content

Ripperton et al (1938) found a highly significant negative correlation (−0.979) between specific gravity and oil content of randomly sampled smooth-shell macadamia kernels. The regression equation y = 212.57 X + 284.70 in which y = percent of oil in the kernel and X = the specific gravity of the kernel relates these two variables linearly. This equation is based on air dried samples containing approximately 3.0 to 3.5 percent moisture.

Because of the ease in measuring specific gravity compared to oil determination, the former method has often been used in determining kernel quality. The relationship between quality, specific gravity and oil in the kernel of *M. integrifolia* is such that Ripperton and his co-workers (1938) considered the following three grades adequate in commercial practice.

Grade 1 consists of kernels having a specific gravity equal to or less than 1.000. Originally this grade was divided into three groups with specific gravities of 1.000 - 0.985, 0.985 - 0.970, and below 0.970. Testing however, indicated there were no important differences in flavor, texture or color between these groups, so they were combined. Kernels in grade 1 contain a minimum of 72 percent oil. Prior to cooking they are plump, well filled, light cream in color and with a smooth surface. When cooked, they are light golden yellow in color with a mild, nutty flavor and crisp texture. The quality is excellent (Ripperton et al 1938).

Grade 2 consists of kernels with specific gravities between 1.000 and 1.025 and oil content between 72 and 67 percent. This group is variable in texture and flavor and definitely inferior to grade 1. The raw kernels are usually slightly shrivelled at the base, and somewhat variable in size and color. The roasted kernels are darker colored than those of grade 1 and have a tendency toward spongy texture and off flavors. Grade 2 kernels are most suitable for the confectionary, baking and dairy (ice cream) trades (Ripperton et al 1938).

Grade 3 consists of kernels with a specific gravity above 1.025 and oil content below 67 percent. The raw kernels are small, hard or tough textured with shrivelled base and off color. When roasted the kernels are very dark colored, hard textured, with an unpleasant burnt flavor. This grade has little or no commercial value in Hawaii (Ripperton et al 1938).

b) Other factors

Hamilton, Mouat and Cameron (1964) list 10 factors (other than oil content) which affect the quality of macadamia nuts grown in Hawaii. They are as follows:

1. Premature natural early drop
2. Borer damage
3. Anthracnose damage and stick-tights
4. Stink bug damage
5. Delay in husking resulting in kernel damage from heating
6. Improper husking resulting in mechanical damage to the kernels
7. Improper or insufficient air-drying
8. Seedling vs. grafted varieties
9. Picking at too long intervals, especially during wet weather
10. Mixing fresh nuts with older nuts.

3. Sample size

Storey (1960) considered a sample of 20-25 nuts to be a good representative sample of the entire crop of a given tree.

4. Handling procedures

a) Harvesting

Macadamia nuts should be harvested only from the ground and sampled within one week of the time of falling (Moltzau and Ripperton 1939). If taken from the tree, immature nuts may be collected, and if left on the ground too long, nuts may develop off-flavor due to germination or mold damage (Storey 1960). Nuts should be husked immediately after harvesting to prevent heating and development of off-flavor (Hawaii Agricultural Experiment Station 1936).

b) Drying and cracking

From their tests Moltzau and Ripperton (1939) considered that 3.5 percent moisture was optimum for cracking the macadamia shell. At this moisture content the kernel is easily loosened from the shell and the shell can be cracked with a minimum of damage to the kernel. They also determined that drying freshly harvested, husked nuts in a stack dryer for two days at 131°F reduced the moisture content to 3.5 percent.

Leverington (1962) reported macadamia nuts contained approximately 3 percent moisture when dried for 2 to 3 days at 140°F in a forced draft dryer after being stored at room temperature for 4 to

5 weeks prior to artificial drying. Both M. integrifolia and M. tetraphylla nuts were included in his determinations.

According to Lee (1968) macadamia nuts reach an equilibrium moisture content of 3.5 percent when dried at 120°F and 33 percent relative humidity; the length of time required depending upon rate of airflow over the nuts.

B. Fruit Development

The perianth and floral disk of macadamia flowers drop soon after fertilization leaving only the pistil attached to the pedicel. By maturity, a small projection at the stylar end of the fruit is all that remains of the long style which has dried and fallen off (Hartung and Storey 1939).

Development of the macadamia fruit can conveniently be divided into two periods; 1) from flowering to 90 days after flowering and 2) from 90 days after flowering to maturity, which occurs about 215 days after flowering in Hawaii (Jones 1957).

During the first 90 days, fruit development consists largely of the laying down of structures and the growth of husk, shell and endosperm (Jones and Shaw 1943). Endosperm development proceeds rapidly between the fourth and eighth weeks after flowering (Hartung and Storey 1939). During this period the shell is soft and white, and the fruit small with a high water content. Sugar increases rapidly and continues to build up but very little oil is formed in the kernel during this period (Jones 1957).

Since no starch is found in the embryo during its development

(Jones 1939), sugars appear to be the most likely substrates for oil production (Jones and Shaw 1943). Jones (1937) found little soluble material in the shell after hardening which takes place in about 120 days. He therefore concluded that after hardening the shell had no important function in formation of oil in the embryo. On the other hand, he found that husks remained relatively high in sugars up until maturity. The husks, which contain chlorophyll, are also active photosynthetically and could contribute to kernel oil formation.

The second development period of the macadamia fruit is characterized by embryo growth and production and storage of oil in the embryo. Total sugars show the greatest increase from the 90th to 126th day after flowering while total oil increases linearly up to maturity (Jones 1939). At maturity the kernel consists largely of oil. By the 20th week after flowering the endosperm has been completely absorbed by the developing cotyledons so that there is no endosperm in mature kernels (Hartung and Storey 1939).

Oil characteristics also change during the period of oil formation and storage. At 90 days the oil consists primarily of short-chain, saturated, free fatty acids but at maturity it is composed mostly of glycerides of long-chain, unsaturated, fatty acids. The acid number, saponification number and percent soluble acids all decrease toward maturity while the percent insoluble acids and iodine number increase (Jones 1957).

Usually one of the two ovules present in the flower aborts after fertilization but occasionally two seeds develop in the same fruit. When this occurs the seeds are hemispherical rather than round. The fruit is a follicle and at maturity the dehiscent pericarp or husk splits along a single suture line. The seeds are harvested from the ground.

C. Factors Affecting Oil Content of Seeds

1. Climate vs. soil type

Garner, Allard and Foubert (1914) experimenting with soy beans, peanuts and sunflowers grown in pots under controlled conditions with a wide range of soil types, concluded that climate was more important than soil type in influencing seed size and oil content of seeds. McNair (1945) arrived at the same conclusion concerning oil content of soy beans, a crop adaptable to a wide range of climatic conditions.

In both instances, the authors found response to soil type depended largely on seasonal conditions, a logical interaction since temperature and precipitation, the two principal components of climate, greatly affect the behavior and functions of soils.

2. General fertility

Within the limits of soil fertility encountered in their studies, soil did not seem to be a major factor in determining seed size or oil content of the seed (Garner et al 1914, McNair 1945).

3. N, P, K, and Fe

a) Nitrogen: Applications of nitrogen have been found to lower the oil content of soy beans, peanuts and sunflower seeds (Garner et al 1914); of soy beans (McNair 1945); and of safflower and flax seed

(Yermanos, Hall and Burge 1964).

b) Phosphorus: Garner and his co-workers (1914) found no change in seed size or oil content due to application of phosphorus. McNair (1945) obtained similar results with soy beans grown in the field, but when grown in pots, phosphorus application increased seed oil content.

c) Potassium: Applications of potassium appeared to have little or no effect on seed size or oil content of the seed (Garner et al 1914, McNair 1945).

d) Iron: Iron chelates applied to flax and safflower growing in the field, had no apparent effect on oil content of the seeds (Yermanos, et al 1964).

D. Pheno-meteorological Approach

1. Agricultural meteorology

Agricultural meteorology may be defined as "that branch of applied meteorology which investigates the responses of living organisms to the physical environment" (Wang 1967) or more specifically, the study of weather phenomena in relation to agricultural production.

As stated by Nuttonson (1965) "the manifold problems of adaptability of a plant variety to its physical and biological environment as well as the problems related to the development of suitable field and orchard management practices and to the development of effective disease and pest control methods, are all in no small degree related to the agroclimatic environment".

2. Agroclimatic Analogue

The term "agroclimatic analogue" used to describe areas similar in those climatic characteristics which affect crop production, is useful in estimating chances of success in introducing a crop to a new area. Nuttonson (1965) considers mean monthly, seasonal, and yearly temperatures; average monthly, seasonal and yearly precipitation and relative humidity; length of frostless period; and latitude, to be the most important elements in predicting crop response. Wang (1967) suggests that analogue methods may be applied to between-localities comparisons when plants are compared at the same stage of growth or in a single locality at different stages of growth.

3. Phenological Approach

Although plant phenologists have concentrated on the study of native plants rather than cultivated crops, the phenological approach can be a useful tool in the study of crop responses. Azzi (1956) stresses the importance of dividing the growing period of a crop into phenological stages based on phenological indicators. For example, in the case of almond: flowering to fruit setting, fruit setting to maximum weight of fruit, maximum weight to ripening of the nut and maturity to end of harvest.

The work of Jones (1957) and Hartung and Storey (1939) established the period of endosperm development, oil formation, and flowering to maturity in macadamia nuts.

4. Meteorological Approach

The meteorological approach places emphasis on climatic factors such as temperature and rainfall, rather than phenological events such as flowering and fruiting. Wang (1967) considered the crop-rainy day; relative-minimum and relative-maximum rainfall; and the interdiurnal temperature to be the most important factors in analysing crop response. He suggested that phenological and meteorological approaches be combined and preliminary analyses carried out with single weather elements such as temperature or rainfall.

E. Climate

1. General

The island of Hawaii, which is the center of the macadamia nut industry, is dominated by two large mountain masses, Mauna Loa and Mauna Kea, both rising above 13,000 feet elevation. The mountainous nature of the island greatly modifies the marine influence resulting in a diversity of climatic conditions (U. S. Dept. of Commerce 1967).

2. Temperature

Trade winds cool the islands during the summer months from May through September, but August and September are still the warmest months of the year. On Hawaii, the southernmost of the Hawaiian Islands, September is usually the warmest month (U. S. Dept. of

Commerce 1967). Based on monthly means, the annual temperature range in Hawaii probably does not exceed 9°F at elevations below 5,000 feet (U. S. Dept. of Commerce 1967).

3. Rainfall

An inversion layer between 5,000 and 7,000 feet above sea level generally lies over Hawaii much of the year and restricts moist air and clouds to below this level. Heaviest rainfall characteristically occurs in the mountains and along windward coasts while low rainfall areas are along the leeward coasts and leeward locations in the interior of the islands. In some areas the annual rainfall gradient may exceed 25 inches per mile. Winter is the rainy season at elevations below 2,000 feet except at Kona where both rain and wind patterns differ from those of the rest of the State (U. S. Dept. of Commerce 1967).

METHODS AND MATERIALS

A. Design

An experiment was established in September, 1968 to study variability in kernel quality, nut size, shell thickness, kernel recovery, and stink bug injury in *Macadamia integrifolia* var. 'Keauhou', the most widely cultivated clone in the State. Samples were taken at random from 2 trees each at 21 sampling locations on three harvest dates. Samples were harvested from the ground under each tree and in order to insure the selection of fresh mature nuts, only those with green husks were taken. The same trees were used for each harvest period.

The three harvest dates consisted of the last weeks of September, October, and November making a harvest interval of approximately one month. The very early, light harvest which characteristically occurs in July and August was not included because of variable quality reported for these nuts (Ripperton et al, 1938). The sampling locations are described in Table 1.

The data were processed on an IBM Model 360/65 computer located at the Statistical and Computing Center on the Manoa Campus of the University of Hawaii, utilizing programs developed at The Pennsylvania State University and University of California, Los Angeles (Dixon 1968).

Chi-square goodness-of-fit tests were computed according to

Table 1. -- Location of cooperator's orchards

Orchard Ref. No.	Orchard Location	Latitude* (North)	Longitude* (West)	Island	Elev. (ft.)	Cooperator
1	Captain Cook	19°30.1'	155°53.9'	Hawaii	2220	
2	Haiku			Maui	470	H. Taketa
3	Haleakala Exp. Fm.			Maui	2100	U. of H.
4	Honakaa (Makai)	20°06.4'	155°32.4'	Hawaii	800	Honakaa Sugar Co.
5	Honakaa (Mauka)	20°06.1'	155°33.4'	Hawaii	1320	Honakaa Sugar Co.
6	Honomalino	19°11.1'	155°52.4'	Hawaii	1580	Honomalino Agric. Co.
7	Kainaliu (Mauka)	19°31.6'	155°55.8'	Hawaii	1350	Oue
8	Kainaliu (Makai)	19°31.5'	155°56.4'	Hawaii	700	Oue
9	Kalopa	20°01.9'	155°24.6'	Hawaii	1700	Ferreira
10	Kau	19°10.8'	155°30.5'	Hawaii	800	Hawaii Orchards
11	Keaau	19°40.2'	155°01.1'	Hawaii	100	Royal Haw. Mac. Nut Co.
12	Keopuka	19°30.4'	155°55.6'	Hawaii	1300	Fukunaga
13	Kohala	20°13.8'	155°48.3'	Hawaii	550	L. Bond
14	Kolo (Makai)	19°17.2'	155°52.9'	Hawaii	1050	
15	Kolo (Mauka)	19°17.3'	155°52.7'	Hawaii	1250	
16	Kona Branch Sta.	19°32.1'	155°55.6'	Hawaii	1480	U. of H.
17	Kurtistown	19°35.5'	155°04.7'	Hawaii	920	Takejo
18	Malama Ki Exp. Fm.	19°27.5'	154°53.2'	Hawaii	330	U. of H.
19	Waiakea Exp. Fm.	19°39.0'	155°05.0'	Hawaii	550	U. of H.
20	Waimanalo Exp. Fm.			Oahu	90	U. of H.
21	Waimea (Kamuela)	20°01.5'	155°39.5'	Hawaii	2750	Masaki

*Scaled from United States Series of Topographic Maps (scale 1:250,000), Hawaii North and Hawaii South methods outlined by Snedecor and Cochran (1967).

Bartlett's test of homogeneity of variances was computed on an Olivetti Underwood programma 101 desk-top electronic computer.

Spot checks of the various programs were made on a Marchant Model 416-S printing calculator to insure that programs were functioning properly. Statistical methods used were those outlined by Snedecor and Cochran (1967).

Climatological data were taken from records furnished by the United States Department of Commerce, Weather Bureau Pacific Region, Climatological Division. The descriptions of climatological stations located in or near the orchards under study are given in Table 2, and are based on information contained in Report R34 of the Hawaii Department of Land and Natural Resources (State of Hawaii 1970).

B. Procedures

Samples were collected by personel of the University of Hawaii Agricultural Experiment Station and husks removed within 24 hours after harvesting.

Nut samples were dried in a forced draft dryer at a temperature of approximately 50°C (122°F) for 4 days. After drying, individual samples were placed in paper bags and stored in large plastic bags which were kept in a sealed polyethylene container.

The container was stored in a cool location in an open room at room temperature from October 1968 through February 1969. The samples were measured in the same order (harvest date) as received so that for each group of samples two to three months elapsed between the time the

Table 2. -- Location of climatological stations furnishing rainfall data* near cooperator's orchards

Orchard Ref. No.	Climatological Station	Latitude (North)	Longitude (West)	Elev. (ft.)	Temperature Readings	USWB Index No.	State Key No.
1							
2	Pauwela	20°55'	156°19'	485			490.0
3	Haleakala BES	20°51'	156°18'	2100			434.0
4	Waikoloa Stream	20°06.3'	155°31.8'	975			208.0
5	Anuenue	20°05.7'	155°32'	1470			209.0
6	Okoe	19°10.1'	155°52'	1590			2.17
7	Hokukano Mauka	19°31.6'	155°55.6'	1410			73.9
8	Hokukano Makai	19°31.6'	155°56.7'	500			73.8
9	Field 30	20°02.1'	155°23.8'	1440			221.2
10	Pahala	19°12.1'	155°28.8'	870	Daily	7421	21.0
11	Keaau Orchard	19°38.7'	155°00.8'	90			92.2
12	Kaawaloa	19°29.7'	155°55.2'	1340		2327	29.0
13	Kohala Mission	20°13.7'	155°47.7'	537	Daily	4680	175.1
14							
15	Opihihale 2	19°16.3'	155°52.6'	1270	Daily	7166	24.1
16	Kainaliu	19°32.2'	155°55.6'	1500	Recorder	2751	73.2
17	Kurtistown	19°34.7'	155°04.2'	920			91.4
18							
19	Waiakea Exp. Fm.	19°38.9'	155°05'	605	Daily		88.8
20							
21	Kamuela	20°01.4'	155°40.2'	2670	Daily	3077	192.2

*Based on information contained in Report R-34 prepared by the Hawaii Department of Land and Natural Resources (1970) and Climatological Data of the U. S. Department of Commerce.

first samples were received and the last samples of that particular group were measured. Studies of in-shell storage of this variety by Cavaletto, Ross, and Yamamoto (1968) indicate that this procedure does not adversely affect quality.

As samples were removed from the storage container they were redried for 2 to 3 days at 50°C prior to taking measurements. They were then weighed on a Mettler analytical balance to the nearest tenth of a gram.

Following weighing, 50 nuts were selected at random, from each sample, and individual shell diameters (length and width) were measured to the nearest 64th inch with a 3-inch pocket slide caliper. The length was measured from apex (micropyle) to the base (funiculus) and the width was measured across the suture (at right angles to the plane of the suture) and at its' center. Nuts were cracked by splitting them along the suture with modified vise-grip pliers with the movable jaw sharpened into a blade (Hamilton 1959).

Kernels were checked for smooth, plump, disease-free appearance. Badly shrivelled, obviously immature, and spoiled kernels were replaced with sound nuts of equal diameter and discarded kernels together with their shells were returned to be weighed again with the remainder of the original sample not used. By subtracting this weight from the original weight of the entire sample, the weight of the final 50-nut sample was obtained.

Shell thickness was measured to the nearest 64th inch both at the side of the shell halfway between apex and base, and at the base. Since the suture side of the shell is generally thicker than the opposite side both sides were measured and averaged.

Stink bug injury was recorded as percent of kernels having one or more spots due to stink bug feeding and determined by use of the formula:

$$\frac{\text{Number of kernels showing injury}}{\text{Total number of kernels in sample}} \times 100 = \text{percent stink bug injury}$$

The kernel samples were then weighed and the percent kernel recovery determined by the use of the formula:

$$\frac{\text{Total kernel weight}}{\text{Total nut weight (kernel plus shell)}} \times 100 = \text{percent kernel recovery}$$

Quality was measured by the flotation method described by Moltzau and Ripperton (1939). Kernels from each 50-nut sample were immersed in tap-water and stirred vigorously to remove air bubbles. Kernels which floated were skimmed off and counted as grade 1. The sinkers were surface dried by blotting with paper towels and then placed in a salt solution made up from 5 1/2 ounces (156 grams) of sodium chloride per gallon of water. Those kernels which floated in this salt solution were skimmed off and counted as grade 2. The remaining sinkers were considered grade 3.

RESULTS

A. Statistical Summary

Parameters of 11 variables estimated from the measurements made in this experiment are shown in Table 3. This summary includes the means of all 123, fifty-nut samples taken on all harvest dates and all locations included in the study. Means from Waimea were included in these estimates although they contained only half the number of samples as the other locations. This was done to include a high elevation location for this variety.

B. Correlations

A correlation matrix for the nut characters measured in this study and in addition, age of trees, average annual rainfall and elevation, is shown in Table 4. This table is also based on the means of all 123, fifty-nut samples.

C. Sample Means

Original sample means for nut weight, kernel weight, percent kernel recovery, percent kernels showing stink bug injury, percent grade 1 kernels, percent grade 2 kernels, percent grade 3 kernels, shell width, shell length, shell thickness at the base, and shell thickness at the side are shown in Appendix Tables 14 through 24.

Table 3. -- Statistical summary of mean, standard error, standard deviation, coefficient of variation (percent), variance, skewness (alpha 3), and kurtosis (alpha 4) based on 123, fifty-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Variable	Mean	St. Error	St. Dev.	CV (%)	Variance	Alpha 3	Alpha 4
1 Nut weight (grams)	7.23	0.058	0.638	8.8	0.407	-0.19	2.80
2 Kernel weight (grams)	2.81	0.039	0.437	15.6	0.191	-0.77**	3.47
3 Percent kernel recovery	38.76	0.425	4.715	12.2	22.233	-0.93**	3.77*
4 Percent stink bug injury	3.45	0.692	7.671	222.5	58.839	3.01**	12.38**
5 Percent grade 1 kernels	84.46	1.428	15.839	18.8	250.874	-1.38**	3.98*
6 Percent grade 2 kernels	9.19	0.891	9.887	107.6	97.743	1.79	6.08**
7 Percent grade 3 kernels	6.35	0.782	8.673	136.6	75.229	2.33**	9.63**
8 Shell width (1/64th in.)	61.93	0.174	1.931	3.1	3.730	-0.54**	3.04
9 Shell length (1/64th in.)	61.57	0.156	1.733	2.8	3.002	-0.21	3.25
10 Shell base thickness (1/64th in.)	9.70	0.093	1.028	10.6	1.057	0.93**	4.43**
11 Shell side thickness (1/64th in.)	6.51	0.062	0.685	10.5	0.469	0.96**	3.95*

Note: Skewness (alpha 3) = 0 and kurtosis (alpha 4) = 3 for normal curve

*equals or exceeds the 5% percentage points
**Equals or exceeds the 1% percentage points

Table 4. -- Correlation coefficients for 14 variables concerning *Macadamia integrifolia* var. 'Keauhou'

	Variable	1	2	3	4	5	6	7
1.	Nut weight (avg.)	1.000						
2.	Kernel wgt. (avg.)	0.656	1.000					
3.	Percent kernel recovery	0.153	0.842	1.000				
4.	Percent kernels stink bug injured	0.110	0.101	0.049	1.000			
5.	Percent grade 1 (by count)	0.243	0.579	0.599	0.235	1.000		
6.	Percent grade 2 (by count)	-0.169	-0.557	-0.620	-0.228	-0.873	1.000	
7.	Percent grade 3 (by count)	-0.250	-0.422	-0.387	-0.169	-0.831	0.454	1.000
8.	Shell width	0.906	0.745	0.338	0.080	0.185	-0.221	-0.082
9.	Shell length	0.896	0.531	0.062	0.035	0.020	-0.031	0.003
10.	Shell base thickness	0.144	-0.553	-0.829	0.003	-0.323	0.393	0.141
11.	Shell side thickness	0.030	-0.657	-0.891	0.012	-0.399	0.492	0.167
12.	Age of trees	0.291	0.661	0.651	0.095	0.157	-0.228	-0.027
13.	Annual rainfall (inches)	-0.201	-0.070	0.072	-0.220	-0.122	0.001	0.221
14.	Elevation (feet)	0.168	0.201	0.125	-0.210	-0.261	0.254	0.187

(Continued)

	Variable	8	9	10	11	12	13	14
8.	Shell width	1.000						
9.	Shell length	0.943	1.000					
10.	Shell base thickness	-0.008	0.238	1.000				
11.	Shell side thickness	-0.149	0.128	0.849	1.000			
12.	Age of trees	0.430	0.253	-0.532	-0.628	1.000		
13.	Annual rainfall (inches)	-0.097	-0.141	-0.054	-0.141	0.037	1.000	
14.	Elevation (feet)	0.189	0.176	-0.258	-0.168	0.217	-0.221	1.000

$r_{0.05} = 0.177$ $r_{0.01} = 0.211$ $n = 123$

D. Distributions and Chi-square Goodness of Fit Tests

Appendix Tables 25 through 34 show the distributions and chi-square goodness of fit to the normal distribution curve for nut weight, kernel weight, percent kernel recovery, percent grade 1 kernels, percent grade 2 kernels, percent grade 3 kernels, shell width, shell length, shell thickness at the base, and shell thickness at the side.

E. Skewness and Kurtosis

The chi-square test does not distinguish between different kinds of non-normality and in this respect may be considered a non-specific test (Snedecor and Cochran 1967).

Skewness occurs when the mean and the mode of a population are not equal. It's measurement is called the third moment about the mean (alpha 3). In populations with positive skewness the upper tail of the distribution is extended, while with negative skewness the lower tail is the extended one. The normal curve has zero skewness.

Kurtosis is estimated by the fourth moment about the mean, (alpha 4) and is a measure of the flatness or peakedness of a population. For the normal curve it has a value of 3. Peaked distributions have values greater than 3 while flat-topped distributions have values below three.

Alpha 3 and alpha 4, showing the skewness and kurtosis respectively of the distributions of the variables measured in this study are shown in Table 3.

F. Analysis of Variance

Analyses of variance combining locations were run for nut weight, kernel weight, percent kernel recovery, percent grade 1 kernels, percent grade 2 kernels, percent grade 3 kernels, shell width, shell length, shell thickness at the base, and shell thickness at the side. Results of these analyses are shown in Appendix Tables 38 through 47. Partitioning of sums of squares is based on a split-plot design in which sums of squares of individual locations are combined as shown in Table 5.

Table 5. -- Partitioning of sums of squares for individual and combined locations

Individual Location				Combined Locations	
Source	d.f.	X 20 Loc.		Source	d.f.
				Locations	19
Trees	1	20	→	Trees in locations (Error A)	20
				Sub-total (40 trees)	(39)
Harvest Dates	2	40	→	Harvest Dates	2
				Loc. X Dates	38
Error (T X D)	2	40	→	Error B	40
Total	5			Total	119

These analyses are based on original data and do not take into consideration normality of the data or homogeneity of variances, which will be discussed in the following section.

DISCUSSION

A. Shell Characters

1. Tests of normality

Many standard statistical techniques, including analysis of variance, are based on the assumption that the data are normally distributed (Snedecor and Cochran 1967). A non-normal distribution of experimental errors can lead to the acceptance of too many significant results due to a decreased efficiency of the F-test. For example, a failure in the assumption of normality of the experimental data may lead the investigator to believe he is testing at the 5% probability level when he may actually be testing at a higher level (Cochran and Cox 1957).

Three tests of normality applied to the data in this study were; the chi-square goodness of fit test; the test for skewness; and the test for kurtosis (Snedecor and Cochran 1967). Table 6 combines the results of these tests for shell characters. Distributions upon which each chi-square is based are given in Appendix Tables 31 to 34.

None of the computed chi-square values fall at or below the 5% level of probability and based on this test alone it would have to be concluded that there is no evidence of non-normality in distributions of shell characters.

The figures for skewness and kurtosis are more difficult to evaluate because of non-significant chi-squares. As discussed previously, the chi-square test is non-specific while those tests for skewness and kurtosis are specific. Data can be markedly skewed without rejecting the null hypothesis of normality (Snedecor and Cochran 1967), and this is the case presented here.

Table 6. -- Tests of normality for shell characters

Shell Characters	Chi-square	Probability of larger Chi-square	Skewness	Kurtosis
Width	9.23	0.50	-0.54**	3.04
Length	3.32	0.95	-0.21	3.25
Thickness at base	11.56	0.25 - 0.10	0.93**	4.43**
Thickness at side	20.13	0.10 - 0.05	0.96**	3.95**

2. Homogeneity of variances

Another assumption upon which the analysis of variance is based is that of equality of experimental error variances. Le Clerg, Leonard and Clark (1962) state unequivocably that of all the assumptions underlying the analysis of variance, homogeneity of error variances is the most important. They note that to obtain equal variances would require equal control over environmental conditions, and experimental material of the same variability. They also state that "It is generally recognized that, in field experiments with crops, land and weather conditions, this degree of uniformity is seldom attained. Because of this condition, one would expect experimental errors of individual experiments to be different from location to location and from season to season."

Of the several methods available to test homogeneity of variances, Bartlett's test is the best known and most widely used

(Le Clerg et al 1962). However, in handling the large amount of data in this study, a quicker test was deemed expedient. Several of these are available including the ratio of the largest to the smallest variance:

$$s^2 \text{ max.} / s^2 \text{ min.}$$

and the ratio of the largest to the sum of the variances:

$$s^2 \text{ max.} / \sum_{t=1}^{k} s^2$$

Values corresponding to the five and one percent levels for these ratios are given in Tables 31 and 31a of Biometrica Tables for Statisticians (Pearson and Hartley 1966). These ratios although slightly less sensitive than Bartlett's test, are quicker to compute and usually adequate in deciding the issue (Snedecor and Cochran 1967).

a) Homogeneity among variances of different trees

Where only two variances are involved, their homogeneity may be tested using a two-tailed F-test (Pearson and Hartley 1966, Snedecor and Cochran 1967). This calculation for shell width is presented in Appendix Table 48 for individual nut measurements from each pair of trees at each location on each harvest date. Waimea is not included since only one tree was available for sampling at that location. The F-test is based on 49 degrees of freedom for each variance and the 0.025 and 0.005 percentage points to give the 5% and 1% levels of probability in a two-tailed test. Similar calculations for the other shell characters are presented in Appendix

Tables 49-51.

About half of the locations appear to be free from heterogeneity, insofar as comparisons between trees are concerned. Heterogeneity does not appear to be limited to any particular harvest date, nor is it general over all harvest dates at any one location, i.e., there appears to be an interaction causing the trees at some locations to be more variable at one time than another. Four hundred eighty analyses of variance were required to obtain the sample variances for the 240 F-tests. Of these, 26 or approximately 11% showed significant heterogeneity at least twice that which would be expected to occur due to chance variation.

b) Homogeneity among variances of different harvest dates

An analysis of variance, based on a one-way classification between trees, was computed for each location and each harvest date for the four shell characters under study. This involved 240 separate analyses with the sums of squares being partitioned as follows:

Source	d.f.
Between trees	1
Between nuts within trees	98
Total	99

The error mean squares for these analyses are shown in Appendix Tables 52-55. The F-test showed significant differences between trees in 22 to 38% of the cases for shell characters studied. Significant differences between trees have been indicated for convenience by placing astericks next to the appropriate error mean square.

Homogeneity of seasonal variances (harvest dates) was tested by taking the ratio of the largest to the sum of the error mean squares at each location (Pearson and Hartley 1966). Bartlett's chi-square test was run in instances where the quick ratio test indicated heterogeneity among the variances or where the outcome was doubtful. The ratio test, in this case, appears to have given a more conservative estimate of heterogeneity than did Bartlett's test. Heterogeneity among seasonal variances (harvest dates) occurred at 7 out of 20 locations (35%) for shell width and at 6 out of 20 locations (30%) for shell length, considerably more times than would be expected due to chance alone. One out of 20 locations (5%) showed heterogeneity among seasonal variances for shell base thickness which is precisely what would be expected at odds of 19 to 1. The shell side thickness variances appeared homogeneous.

c) Homogeneity of comparisons between locations

An analysis of variance was run at each location, involving a total of 80 separate analyses, to obtain the experimental error mean squares shown in Appendix Table 56. Partitioning of the sums of squares was as follows:

Source		d.f.
Trees		1
Harvest Dates		2
Experimental Error		2
Sampling Error		294
	Total	299

Homogeneity was tested for comparisons between locations. Only shell thickness measurements showed heterogeneous variances, which were reduced to nonsignificance by elimination of the underlined variances in Appendix Table 56. The adjusted ratio and chi-square figures shown in the table are based on tests of the remaining homogeneous variances.

B. Quality Characters

1. Transformations

Transformations are needed where variance stabilization or normalization is required (Snedecor and Cochran 1967). Because of this, data for grades 1, 2, and 3 were transformed to the angular scale in which angle = arcsin $\sqrt{\text{percentage}}$ using tables prepared by C. I. Bliss and contained in Statistical Methods (Snedecor and Cochran 1967). Distributions of transformed data and computations for chi-square goodness of fit test for each variable are presented in Appendix Tables 35-37.

There is a considerable reduction in the chi-square values of the transformed data over that of the original data summarized as follows:

	Percent Grade 1	Percent Grade 2	Percent Grade 3
Chi-square based on original data	106.95**	86.49**	34.18**
Chi-square based on transformed data	69.25**	43.11**	18.36*

These values have not, however, been reduced to non-significance.

While it does not appear that the transformed data will give a good fit to the normal curve in every case, appreciable gain has been made in reducing heterogeneity in the experimental error mean squares.

There is general agreement (Le Clerg, Leonard and Clark 1962; Cochran and Cox 1957; and Snedecor and Cochran 1967) that some non-normality exists in much biological data, but in most cases this does not invalidate the effectiveness of analysis of variance.

The analysis of variance for the combined locations using the transformed data for percent grade 1 is given in Table 7.

Table 7. -- Analysis of variance of combined locations using transformed data for percent grade 1 kernels of *Macadamia integrifolia* var. 'Keauhou'

Source	d.f.	Mean Square	F
Locations	19	603.91	8.10**
Trees within loc. (Error A)	20	74.58	
Harvest Dates	2	54.51	2.14
Loc. X Dates	38	86.88	3.40**
Error B	40	25.52	

In comparison with the analysis of variance performed on the data in the original scale (Appendix Table 41), the transformation appears to have made little change in the significance of the variance ratios.

Appendix Table 59 presents F-values obtained by analysing the same data by individual locations, in both original and transformed scales. The transformation has also not greatly affected the interpretation of this data.

2. Homogeneity of variances between locations

Experimental error mean squares for percent grades 1, 2, and 3 in the original scale, and grade 1 in the transformed scale are given in Appendix Table 57. Procedures for testing homogeneity of variances are the same as those described previously. Heterogeneity, found in the original scale, for all except percent grade 2 data, has been reduced to non-significance by removing variances underlined in Appendix Table 57. Adjusted ratio and chi-square values are listed at the bottom of Appendix Table 57. As noted previously for percent grade 1 data, use of the angular scale has produced homogeneity among variances without having to eliminate any locations from the analysis.

C. Weight Characters

1. Homogeneity of variances

A total of sixty analyses of variance were run for the three variables: nut weight, kernel weight and percent kernel recovery, in order to obtain the experimental error mean squares for each location shown in Appendix Table 58. Partitioning of sums of squares and procedures for testing homogeneity among the variances were the same as those described previously. Both kernel weight and percent kernel recovery showed significant heterogeneity which was removed by eliminating the underlined variances from the tests, as indicated by the adjusted ratio and chi-square values at the bottom of the table.

D. Pheno-meteorological Relationships

1. General

Rainfall data were available for 17 and temperature data for 6 of the 21 locations sampled in this study, as indicated in Table 2. For the 17 locations where rainfall data were available, simple linear correlations were calculated utilizing various rainfall combinations. These included relative minimum and relative maximum rainfall (Wang 1967) for consecutive 1, 2, 3, and 4-month periods during the 9 months preceding harvest, and total rainfall during phenological stages of growth. Phenological stages consisted of the two months prior to flowering, the three months after flowering, and the four months prior to harvest. The latter two periods correspond to the periods of endosperm development and oil formation, respectively, (Jones 1957). These periods were estimated by counting back from harvest dates.

For the 6 locations where temperature data were available, similar correlations were made utilizing various combinations of monthly maximum, minimum, and average temperatures. Based on these correlations with rainfall and temperature data, independent variables were selected for further testing and screening in a stepwise multiple regression BMD02R program (Dixon 1968). Both simple linear correlations and multiple linear regression coefficients were calculated. These and subsequent analyses were limited to the 6 locations where both temperature and rainfall data were available.

The 6 locations used, represent a wide range of climatic conditions for the lower elevations of the island of Hawaii and are well distributed geographically. They include the youngest and oldest trees sampled in the study and range in elevation from 550 to 2,750 feet. The 1968 annual mean temperature range of these locations, based on monthly averages, was from 4.8°F to 6.8°F and their annual rainfall ranged from about 50 to 175 inches that year. This information is shown in Table 8.

2. Simple correlations between independent variables

There were highly significant negative correlations between temperatures and elevations. These correlations, ranging from -0.941 to -0.968, are shown in Table 9 under the column heading ELEV.

In analysing rainfall data, strong positive correlations were found between summer rainfall and relative minimum rainfall[1] reflecting the fact that the driest weather occurred during this period. The summer of 1968 was especially dry, with four stations on Hawaii reporting lower rainfall than in any previous June (U. S. Dept. of Commerce, June 1968). The dry spell was not broken until September of that year (U. S. Dept. of Commerce, Sept. 1968). The correlations ranged from 0.749 (JULY vs. RM1MO) to 0.980 (JUNE vs. RM4MO).

Correlations between relative minimum rainfalls and rainfall during the phenological growth stages suggested a progressive shift toward dryer conditions as the crop developed to maturity. Correlations between relative minimum rainfalls and rainfall during the 2 months prior to flowering are shown in Table 9 in the column headed

[1]Relative minimum rainfall is the lowest accumulation of rainfall in a given period for a specific growing season (Wang 1967). In this study the periods were for 1, 2, 3, and 4 months and the growing season was considered to be from 2 months before flowering to harvest. For instance, the relative minimum rainfall for 3 months consisted of the lowest accumulation of rainfall for any three consecutive months occurring within the nine months between pre-flowering and harvest.

RAIN2M. They range from 0.461 to 0.521. Correlations for rainfall during the 3 months after flowering (RAIN3M) ranged from 0.735 to 0.785 and for the 4 months prior to harvest (RAIN4M) from 0.917 to 0.971.

Table 8. -- Elevations, rainfall, and temperatures at six locations on the island of Hawaii

Orchard Ref. No.	Location	Elev. (ft.)	Annual Rainfall 1968 (in.)	Annual Mean Temp. 1968 (°F)	Annual Mean Temp. Range 1968 (°F)
10	Kau	800	86.2	72.3	5.7
13	Kohala	550	78.6	73.9	6.1
15	Kolo (Mauka)	1,250	54.5	70.3	6.8
16	Kona Branch Sta.	1,480	69.4	71.5	5.6
19	Waiakea Exp. Fm.	550	175.7	73.4	4.8
21	Waimea (Kamuela)	2,750	50.3	65.5	5.7

3. Simple correlations between dependent variables

Correlations between nut characters studied are given in Table 10. Significant correlations were found between certain groups of variables. The quality characters, grades 1, 2 and 3, form one such group, with highly negative correlations between grade 1 and the lower grades and a smaller, but high significant, positive correlation between grades 2 and 3. As quality increased percent kernels in grades 2 and 3 decreased.

A second group comprises characters which measure overall size: shell length, shell width, nut weight, and kernel weight. High positive correlations were found between all of these indicating that the larger the shell diameter the larger the nut weight and the

Table 9. -- Simple correlations between independent variables at 6 locations on the island of Hawaii

	DATES	JUNE	JULY	AUG	SEPT	RM1MO	RM2MO	RM3MO	RM4MO
DATES	1.000	0.000	0.000	0.000	0.000	0.001	-0.029	-0.027	-0.032
JUNE		1.000	0.842	0.933	0.867	0.973	0.988	0.976	0.980
JULY			1.000	0.849	0.698	0.749	0.802	0.879	0.893
AUG				1.000	0.926	0.946	0.942	0.943	0.965
SEPT					1.000	0.923	0.922	0.900	0.911
RM1MO						1.000	0.988	0.950	0.958
RM2MO							1.000	0.979	0.981
RM3MO								1.000	0.922
RM4MO									1.000

Key to abbreviations used in table

DATES = harvest dates
JUNE = rainfall during June
JULY = rainfall during July
AUG = rainfall during August
SEPT = rainfall during September
RM1MO = relative minimum rainfall for 1 month
RM2MO = relative minimum rainfall for 2 months
RM3MO = relative minimum rainfall for 3 months
RM4MO = relative minimum rainfall for 4 months
RAIN2M = total rainfall during 2 months prior to flowering
RAIN3M = total rainfall during 3 months after flowering
RAIN4M = total rainfall during 4 months prior to harvest
TEMP2M = average temperature during 2 months prior to flowering
TEMP3M = average temperature during 3 months after flowering
TEMP4M = average temperature during 4 months prior to harvest
TEMP7M = average temperature during 7 months from flowering to harvest
TEMP9M = average temperature during 9 months preceding harvest
AGE = age of trees
ELEV = elevation of trees

$r_{0.05} = 0.468$

$r_{0.01} = 0.590$

$n = 18$

Table 9. -- (Continued) Simple correlations between independent variables at 6 locations on the island of Hawaii

	RAIN2M	RAIN3M	RAIN4M	TEMP2M	TEMP3M	TEMP4M	TEMP7M	TEMP9M	AGE	ELEV
DATES	0.271	-0.406	-0.018	0.162	0.262	0.029	0.130	0.138	-0.000	0.000
JUNE	0.582	0.787	0.929	0.591	0.514	0.505	0.513	0.533	-0.302	-0.532
JULY	0.345	0.588	0.862	0.719	0.655	0.637	0.650	0.669	-0.167	-0.584
AUG	0.352	0.667	0.921	0.507	0.467	0.445	0.458	0.472	-0.335	-0.442
SEPT	0.287	0.575	0.923	0.399	0.376	0.321	0.348	0.361	-0.654	-0.406
RM1MO	0.521	0.757	0.917	0.533	0.477	0.462	0.473	0.489	-0.382	-0.515
RM2MO	0.505	0.785	0.949	0.547	0.472	0.458	0.468	0.488	-0.415	-0.512
RM3MO	0.461	0.747	0.968	0.605	0.528	0.511	0.523	0.544	-0.397	-0.545
RM4MO	0.455	0.735	0.971	0.597	0.527	0.510	0.522	0.541	-0.380	-0.535
RAIN2M	1.000	0.336	0.340	0.416	0.418	0.377	0.399	0.404	0.056	-0.406
RAIN3M		1.000	0.663	0.397	0.230	0.354	0.304	0.326	-0.068	-0.378
RAIN4M			1.000	0.600	0.532	0.497	0.516	0.538	-0.513	-0.550
TEMP2M				1.000	0.973	0.967	0.979	0.987	-0.020	-0.949
TEMP3M					1.000	0.961	0.987	0.988	-0.035	-0.941
TEMP4M						1.000	0.993	0.991	-0.072	-0.968
TEMP7M							1.000	0.999	-0.027	-0.966
TEMP9M								1.000	0.016	-0.966
AGE									1.000	0.126
ELEV										1.000

$r_{0.05} = 0.468$

$r_{0.01} = 0.590$

$n = 18$

Table 10. -- Simple correlations between dependent variables at 6 locations of the island of Hawaii

	GRADE1	GRADE2	GRADE3	WIDTH	LENGTH	NUTWGT	KERWGT	PCTREC	BASE	SIDE
GRADE1	1.000	-0.911	-0.887	0.118	0.092	-0.086	0.358	0.478	0.072	0.123
GRADE2		1.000	0.626	-0.048	0.022	0.258	-0.335	-0.612	0.092	0.108
GRADE3			1.000	-0.198	-0.242	-0.153	-0.273	-0.162	-0.315	-0.422
WIDTH				1.000	0.969	0.797	0.745	0.053	0.366	0.365
LENGTH					1.000	0.812	0.583	0.138	0.536	0.566
NUTWGT						1.000	0.519	-0.370	0.366	0.430
KERWGT							1.000	0.601	-0.241	-0.213
PCTREC								1.000	-0.617	-0.640
BASE									1.000	0.877
SIDE										1.000

Key to abbreviations used in table

GRADE1 = percent grade 1 kernels
GRADE2 = percent grade 2 kernels
GRADE3 = percent grade 3 kernels
WIDTH = shell width
LENGTH = shell length
NUTWGT = nut weight
KERWGT = kernel weight
PCTREC = percent kernel recovery
BASE = shell thickness at base
SIDE = shell thickness at side

$r_{0.05} = 0.468$

$r_{0.01} = 0.590$

$n = 18$

greater the kernel weight.

The third group comprises nut characters related to kernel recovery and includes percent kernel recovery, and shell thickness at the base and side. As shell thickness increased, kernel recovery decreased as shown in Table 10.

Kernel weight was correlated with nut size as well as with kernel recovery. It showed the same negative relationship with shell thickness as kernel recovery, suggesting that it may fit into this group as well as the previous group. Subsequent analysis indicated that kernel weight should be with the kernel recovery group.

4. Simple correlations between dependent and independent variables

Quality characters, particularly grades 1 and 2, are correlated with temperature periods and elevation (Table 11). Percent grade 1 kernels increased with increased temperature and decreased with elevation, reflecting the negative correlation between elevation and temperature discussed previously. Percent grade 2 and 3 kernels on the other hand, decreased with increased temperature and increased with elevation.

All of the variables measuring rainfall (Table 11) were positively correlated with percent grade 1 kernels and negatively correlated with grades 2 and 3. This follows the pattern of negative correlation between grade 1 and the two lower grades, discussed previously. Significant correlations between quality, and summer and relative minimum rainfall are evident in most instances (Table 11), particularly for grades 1 and 2. Correlations between quality and phenological rainfall were significant only for the period of oil formation (RAIN4M).

Since summer rainfall and relative minimum rainfall occurred during the driest part of the year in 1968 and coincided with the period of oil formation, it seems logical to assume that there probably is an effect of increased rainfall in improving kernel quality when dry weather occurs during the period of oil formation.

Simple correlations involving nut size characters indicate that shell length and width, and nut weight were principally influenced by rainfall occurring during the two months prior to flowering and the three months following flowering (Table 11). In every case increased rainfall had a negative effect on size and the strongest correlations were with rainfall during the two months prior to flowering. Kernel weight followed the same trend but the correlations found were not significant.

Why increased rainfall during the two months prior to flowering should negatively affect overall size of the nut is not readily apparent. However, if it is considered that rainfall is also a measure of cloudiness, then it is logical to assume that increased rainfall is related to increased cloudiness and reduced photosynthesis, thereby affecting the carbohydrate status of the tree. Cloudy weather conditions during March and April 1968 support this hypothesis. Unusually cloudy weather was reported for the entire State during March 1968 (U. S. Dept. Commerce, March 1968). In April 1968 Hilo reported only 17 percent of possible sunshine (U. S. Dept. Commerce, April 1968) which is about half the expected amount for

Table 11. -- Simple correlations between dependent and independent variables at 6 locations on the island of Hawaii

	DATES	JUNE	JULY	AUG	SEPT	RM1MO	RM2MO	RM3MO	RM4MO
GRADE1	0.246	0.520	0.612	0.570	0.492	0.531	0.510	0.545	0.554
GRADE2	-0.025	-0.524	-0.708	-0.519	-0.424	-0.480	-0.495	-0.556	-0.569
GRADE3	-0.389	-0.390	-0.356	-0.508	-0.493	-0.476	-0.417	-0.406	-0.416
WIDTH	-0.011	-0.479	-0.190	-0.179	-0.253	-0.396	-0.449	-0.415	-0.366
LENGTH	0.052	-0.512	-0.298	-0.207	-0.198	-0.389	-0.453	-0.439	-0.395
NUTWGT	0.069	-0.468	-0.346	-0.195	-0.225	-0.356	-0.425	-0.435	-0.391
KERWGT	0.040	-0.183	0.191	0.015	-0.261	-0.225	-0.245	-0.165	-0.120
PCTREC	-0.006	0.243	0.536	0.197	-0.078	0.091	0.136	0.231	0.238
BASE	-0.033	-0.094	-0.296	0.066	0.280	0.119	0.031	-0.047	-0.042
SIDE	0.346	-0.130	-0.271	0.056	0.290	0.063	-0.014	-0.076	-0.062

	RAIN2M	RAIN3M	RAIN4M	TEMP2M	TEMP3M	TEMP4M	TEMP7M	TEMP9M	AGE	ELEV
GRADE1	0.199	0.239	0.578	0.827	0.857	0.830	0.850	0.848	-0.097	-0.802
GRADE2	-0.255	-0.287	-0.593	-0.902	-0.904	-0.914	-0.918	-0.918	0.078	0.890
GRADE3	-0.046	-0.125	-0.447	-0.557	-0.619	-0.561	-0.591	-0.586	0.165	0.550
WIDTH	-0.684	-0.494	-0.335	-0.158	-0.055	-0.064	-0.060	-0.083	0.235	0.172
LENGTH	-0.707	-0.563	-0.333	-0.222	-0.102	-0.140	-0.124	-0.147	0.066	0.199
NUTWGT	-0.614	-0.455	-0.369	-0.360	-0.286	-0.289	-0.291	-0.308	0.188	0.376
KERWGT	-0.355	-0.207	-0.161	0.160	0.200	0.241	0.225	0.211	0.605	-0.027
PCTREC	0.195	0.212	0.172	0.529	0.499	0.545	0.531	0.532	0.491	-0.394
BASE	-0.285	-0.135	0.023	-0.129	-0.039	-0.088	-0.068	-0.082	-0.456	-0.045
SIDE	-0.272	-0.365	0.029	-0.133	-0.004	-0.150	-0.089	-0.099	-0.544	0.036

Refer to tables 9 and 10 for keys to abbreviations

$r_{0.05} = 0.468$ $r_{0.01} = 0.590$ $n = 18$

that month.

Of the remaining 4 nut characters summarized in Table 11, age of tree appeared to be the most important common single factor. Both kernel weight and percent kernel recovery increased with increasing age of tree, while shell thickness decreased with age. This agrees with observations made from correlations among dependent variables in Table 10, that both kernel weight and percent kernel recovery are inversely related to shell thickness.

E. Factors Affecting Nut Characters

In the final stepwise multiple regression analyses for nut characters, independent variables were limited to age of tree, harvest date, and average temperature and total rainfall for the phenological periods. These variables were selected from preliminary regression analyses in which the independent variables listed in Table 9 were tried in different combinations. Results are shown in Table 12. Variables are tabulated in decreasing order of importance based on partial F values due to regression. They represent the three variables with highest F values of the 8 variables tested in the final regression equation.

1. Quality characters

Percent grade 1 kernels increased with increased temperature during the period of endosperm development. None of the other variables tested showed any significant effect on percent grade 1 kernels.

Table 12. -- Factors affecting nut characters of *Macadamia integrifolia* var. 'Keauhou' at 6 locations on the island of Hawaii

QUALITY CHARACTERS	Main Factor	Effect	F Value	2nd Factor	Effect	F Value	3rd Factor	Effect	F Value
GRADE1	TEMP3M	positive	31.65**	RAIN2M	negative	2.74	RAIN4M	positive	2.03
GRADE2	TEMP4M	negative	68.00**	RAIN4M	negative	7.28*	RAIN3M	positive	2.97
GRADE3	DATES	negative	36.81**	TEMP4M	negative	29.31**	TEMP2M	positive	21.63**
SIZE CHARACTERS									
WIDTH	RAIN2M	negative	44.65**	TEMP3M	positive	21.91**	TEMP2M	negative	17.34**
LENGTH	RAIN2M	negative	39.49**	TEMP3M	positive	22.91**	TEMP2M	negative	18.40**
NUTWGT	RAIN2M	negative	6.93*	RAIN3M	negative	1.64	AGE	positive	1.08
RECOVERY CHARACTERS									
KERWGT	AGE	positive	43.30**	RAIN2M	negative	23.26**	RAIN4M	positive	10.75**
PCTREC	AGE	positive	7.60*	TEMP4M	positive	2.11	RAIN4M	positive	1.58
BASE	AGE	negative	4.02	RAIN2M	negative	1.40	--	--	--
SIDE	AGE	negative	8.25*	DATES	positive	5.53*	RAIN2M	negative	3.68

*Significance exceeds the 5% point for F
**Significance exceeds the 1% point for F

Refer to Tables 9 and 10 for keys to abbreviations.

Temperature during the period of oil formation was the most important single factor influencing percent grade 2 kernels. The effect was negative indicating that as temperature increased percent grade 2 kernels decreased (Table 12). This decrease is assumed to be in the direction of higher quality since increased temperature during this same period had the effect of reducing percent grade 3 kernels, obviously a shift toward higher quality.

Increased rainfall during the period of oil formation was also significant in reducing percent grade 2 kernels (Table 12). Since increasing rainfall during this same period had the effect of decreasing percent grade 3 kernels (Table 11), the decrease in percent grade 2 kernels is also expected to be in the direction of higher quality.

The most important single factor influencing percent grade 3 kernels was harvest dates. The effect was negative. As the harvest season progressed, percent grade 3 kernels decreased.

Increased temperature during the period of oil formation reduced percent grade 3 kernels. Whenever percent grade 3 kernels is reduced, the overall quality of the sample is improved. Temperature during the 2-month period prior to flowering had a highly significant positive effect on percent grade 3 kernels. The interpretation of this is not clear however.

2. Size characters

The most important single factor influencing shell width, shell length, and nut weight was rainfall during the two months prior to flowering. In all cases rainfall had a negative effect on size and as mentioned previously there is no clear explanation for this phenomena other than a possible inference of reduced photosynthesis due to increased cloudiness.

The two month period preceding flowering occurred during January and February for the September harvest; during February and March for the October harvest; and during March and April for the November harvest. The period from January through April 1968 was characterized by absence of trade winds during January and February and frequent storms accompanied by heavy rains. Waimea (Kamuela) had heavy thundershowers in April, which caused considerable damage to crops in that area, and recorded 13.52 inches, the highest April rainfall in 77 years (U. S. Dept. of Commerce, April 1968). On the other hand, replacement of the trades by southwesterly winds during January and February resulted in below average rainfall in the Hilo-Hamakua area but the western part of the island received more than average rainfall during this period.

3. Kernel recovery characters

Age of tree was the most important single factor influencing kernel weight, kernel recovery, and shell thickness (Table 12). Kernel weight and kernel recovery increased and shell thickness decreased as age of tree increased. The question as to whether kernel weight belongs with the size characters or recovery characters has apparently been resolved since it appears to be affected to a greater degree by age of tree than by rainfall.

The second most important factor determining kernel weight was rainfall during the 2 months before flowering. This effect was negative suggesting that reduction in kernel weight may result from reduced photosynthesis due to increased cloudiness rather than to increased rain.

The third most important factor in determining kernel weight was rainfall during the period of oil formation. This appears to be related to the fact that the period of oil formation during 1968 occurred during the driest part of the year. Increasing the supply of available soil moisture during this period might therefore be expected to increase kernel weight.

Other than age of tree, none of the other variables tested appeared to have any significant effect on percent kernel recovery. Rainfall did not appear to affect kernel recovery although it was the most important variable in determining nut weight. Since kernel recovery is the quotient of kernel weight divided by nut weight such a relationship might have been expected. The lack of influence of rainfall on nut weight is logical, however, taking into consideration that kernel weight was significantly correlated with kernel recovery, but nut weight was not (Table 10).

While age of tree was not significant at the 5% level in accounting for shell thickness at the base, it approached significance at this level. The two shell thickness measurements had a high positive correlation of 0.877 (Table 10). Age of tree had a significant influence on shell thickness at the side, and probably influenced both thicknesses. Harvest dates also appeared to have an important influence on shell thickness at the side. As the harvest season advanced, shells became increasingly thicker at the side.

F. Relation to Previous Work

Hamilton, Mouat and Cameron (1964) reported percent grade 1 kernels for 7 locations in Hawaii, 6 of which are included in the present study. A comparison is made between their data and that of the present study in Table 13.

A 't' test indicates that average kernel quality at these locations in 1968 did not differ from that reported for 'Keauhou' in 1962, but marked changes were noted at individual locations. Keaau Orchard which had the highest quality in 1962 ranked lowest in 1968. Percent grade 1 kernels at Captain Cook in 1968 was more than double that reported in 1962 and Kona showed a 40% increase. The two tailed 'F' test revealed that the two error variances were homogeneous.

Shell thickness and percent kernel recovery have been reported relatively stable at different locations in Hawaii (Hamilton, Cameron and Mouat 1968). The results of this study agree with those findings, at some locations common to both studies. These locations were Captain Cook, Kalopa (Ferreira),Keaau, Kona Branch Station, and Kurtistown (Takajo).

Appendix Table 40 indicates that in 1968 there was no important difference in percent kernel recovery between Kalopa, Kurtistown, and Captain Cook, but Kona was higher and Keaau lower than at the other 3 locations on Hawaii. In comparing shell thickness at the side of the shell in 1968 (Appendix Table 47) all five locations on Hawaii were similar except for Keaau Orchard where shells appeared thicker.

Table 13. -- Comparison of percent grade 1 kernels from 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Location		Percent Grade 1	
		1962*	1968**
Captain Cook		32.3	70.8
Kainaliu (Oue)		80.0	90.3
Kalopa (Ferreira)		64.5	78.7
Keaau		97.0	62.7
Kona Branch Station		65.3	91.8
Kurtistown (Takajo)		89.0	73.8
	Average	71.4	78.0

*means of 4 samples
**means of 6 samples

CONCLUSIONS AND SUMMARY

This experiment was set up to study variation existing within a clone at different harvest dates and different locations in Hawaii. The clone used was 'Keauhou', a variety popular in Hawaii. It has been recommended in California as the most satisfactory of the *M. integrifolia* varieties from the standpoint of production and quality (Calif. Macadamia Soc. Var. Comm. Rep. 1968). It has also been introduced to a number of other tropical and subtropical areas around the world.

Results of this study indicated that nut characters were variable between the locations sampled. Except for shell diameter and percent grade 2 kernels, all other nut characters showed some degree of interaction between locations and harvest dates, i.e., differences found between locations were not consistent but varied with harvest dates and showed no trend.

Seasonal effects were found among the means for shell thickness, percent grade 2 kernels and percent kernel recovery but these were generally weaker than locational effects and showed no consistent trend or pattern. Lack of a consistent trend in differences between trees, between harvest dates, and between locations would pose the greatest obstacle to the use of this variety in experiments without adequate replication.

Variation can be expected when experiments are replicated over seasons or locations, and since macadamia trees occupy rather large plots of land, soil heterogeneity can be a large contributing factor to variability between trees in the same orchard.

When variability shows a consistent trend or can be correlated with some contributing factor such as temperature, sunshine, rainfall or soil moisture, then covariance methods of analysis can be used. By adjusting treatment effects and check-plots to the same standard of comparison, the number of trees needed in the experimental plot can be reduced. Correlations obtained would also aid in predicting the performance of a variety in a given climatic situation.

Through the use of correlation and stepwise multiple regression techniques, relationships were established between nut characters and various independent variables. Groupings of related nut characters were evident. The results of these and other analyses may be summarized as follows:

Quality Characters

Percent grade 1 kernels varied from 41 to 100% and increased as temperature increased during the period of endosperm development.

Percent grade 2 kernels, which varied from 0 to 49%, decreased with increased temperature and increased rainfall during the period of oil formation.

Percent grade 3 kernels varied from 0 to 47% and increased as temperature increased during the 2 months before flowering. Percent grade 3 kernels decreased with increased temperature during the period of oil formation and with advancing harvest dates.

Size Characters

Shell width, which varied from 0.88 to 1.03 inches (56.5/64 to

66.2/64 of an inch), increased with increased temperature during the period of endosperm development and decreased with increased rainfall and temperature during the 2 months before flowering.

Shell length varied from 0.88 to 1.03 inches (56.3/64 to 65.8/64 of an inch) and was similarly influenced by the same factors as shell width.

Nut weight varied from 5.6 to 8.9 grams and appeared to be mainly influenced by rainfall during the 2 months before flowering. The effect was negative as with the other size characters.

Kernel Recovery Characters

Kernel weight which varied from 1.4 to 3.5 grams increased as age of tree increased and with increased rainfall during the period of oil formation. Kernel weight decreased with increased rainfall during the two months before flowering.

Percent kernel recovery varied from 24.0 to 46.5% and increased as age of tree increased.

Shell thickness at the base varied from 0.12 to 0.22 inches (7.9/64 to 13.9/64 of an inch) and showed signs of decreasing with increased age of tree.

Shell thickness at the side varied from 0.08 to 0.13 inches (5.2/64 to 8.6/64 of an inch). It increased as the harvest date advanced and decreased with increased age of tree.

APPENDIX

A

Table 14.--Nut weight, in grams, (kernel plus shell) based on 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Harvest Dates: Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	7.2	7.3	7.8	7.1	8.1	7.1	7.42	7.1	8.1	1.0
2	Haiku	7.7	7.1	6.6	7.0	7.0	7.6	7.14	6.6	7.7	1.1
3	Haleakala Exp. Fm.	7.3	7.3	7.2	7.3	7.3	7.5	7.31	7.2	7.5	0.3
4	Honakaa (Makai)	7.0	6.9	6.9	6.7	8.1	7.0	7.11	6.7	8.1	1.4
5	Honakaa (Mauka)	8.0	8.4	7.9	7.7	7.7	7.3	7.83	7.3	8.4	1.1
6	Honomalino	7.2	6.1	5.8	6.3	6.6	6.5	6.42	5.8	7.2	1.4
7	Kainaliu (Mauka)	7.5	7.8	7.9	7.9	7.8	8.5	7.89	7.5	8.5	1.0
8	Kainaliu (Makai)	7.4	7.7	7.3	7.9	7.2	7.6	7.52	7.2	7.9	0.7
9	Kalopa	7.1	7.5	7.9	7.5	7.1	7.0	7.36	7.0	7.9	0.9
10	Kau	6.0	6.4	6.1	6.4	6.3	6.8	6.35	6.0	6.8	0.8
11	Keaau	7.9	7.5	7.6	6.8	8.2	7.6	7.61	6.8	8.2	1.4
12	Keopuka	8.9	7.7	7.6	7.1	8.1	6.7	7.69	6.7	8.9	2.2
13	Kohala	7.3	7.2	7.5	6.9	7.4	7.4	7.28	6.9	7.4	0.5
14	Kolo (Makai)	6.1	7.0	6.0	7.5	6.9	6.8	6.71	6.0	7.5	1.5
15	Kolo (Mauka)	7.8	7.5	8.2	7.9	7.8	8.5	7.95	7.5	8.5	1.0
16	Kona Branch Sta.	7.7	8.0	7.4	7.7	7.5	7.5	7.64	7.4	8.0	0.6
17	Kurtistown	7.6	6.7	7.8	6.8	6.3	6.7	6.98	6.3	7.8	1.5
18	Malama Ki Exp. Fm.	6.6	6.3	6.7	6.6	7.6	7.1	6.83	6.3	7.6	1.3
19	Waiakea Exp. Fm.	6.7	6.5	6.1	5.9	6.3	5.6	6.19	5.6	6.7	1.1
20	Waimanalo Exp. Fm.	7.4	7.1	7.2	7.2	7.5	7.4	7.31	7.1	7.5	0.4
21	Waimea (Kamuela)	6.4	--	8.4	--	7.1	--	7.31	6.4	8.4	2.0
	Mean		7.26*		7.14*		7.28*	7.23* 7.23**			

*Waimea not included
**Waimea included

Table 15.-- Kernel weight, in grams, based on 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Harvest Dates Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	3.0	3.0	3.3	2.8	3.3	2.8	3.02	2.8	3.3	0.5
2	Haiku	3.5	3.2	3.0	3.2	3.1	3.4	3.24	3.0	3.5	0.5
3	Haleakala Exp. Fm.	3.2	3.1	3.3	3.2	3.3	3.3	3.23	3.1	3.3	0.2
4	Honakaa (Makai)	2.7	2.8	2.8	2.8	3.1	2.9	2.83	2.7	3.1	0.4
5	Honakaa (Mauka)	3.4	3.4	3.4	3.2	3.1	3.0	3.24	3.0	3.4	0.4
6	Honomalino	2.6	1.8	1.7	2.1	2.3	2.1	2.10	1.7	2.6	0.9
7	Kainaliu(Mauka)	3.0	3.3	3.2	3.2	3.0	3.4	3.19	3.0	3.4	0.4
8	Kainaliu(Makai)	2.8	2.8	2.8	2.9	2.8	2.8	2.82	2.8	2.9	0.1
9	Kalopa	2.7	3.0	3.3	3.0	2.9	2.9	2.97	2.7	3.3	0.6
10	Kau	2.4	2.6	2.5	2.7	2.6	2.8	2.58	2.4	2.8	0.4
11	Keaau	2.9	2.8	2.4	2.4	2.7	2.6	2.63	2.4	2.9	0.5
12	Keopuka	3.4	2.9	2.9	2.7	3.1	2.5	2.92	2.5	3.4	0.9
13	Kohala	3.1	3.0	3.3	3.0	3.2	3.1	3.14	3.0	3.3	0.3
14	Kolo (Makai)	1.5	2.1	1.4	2.3	1.8	2.0	1.84	1.4	2.3	0.9
15	Kolo (Mauka)	2.9	2.7	2.9	2.9	2.7	2.4	2.75	2.4	2.9	0.5
16	Kona Branch Sta.	3.3	3.4	3.3	3.4	3.4	3.4	3.36	3.3	3.4	0.1
17	Kurtistown	3.3	3.0	3.2	2.7	2.4	2.3	2.83	2.3	3.3	1.0
18	Malama Ki Exp. Fm.	2.3	2.1	2.5	2.5	2.4	2.1	2.30	2.1	2.5	0.4
19	Waiakea Exp. Fm.	2.7	2.6	2.5	2.4	2.5	2.2	2.49	2.2	2.7	0.5
20	Waimanalo Exp. Fm.	2.7	2.6	2.7	2.8	2.9	2.7	2.73	2.6	2.9	0.3
21	Waimea (Kamuela)	2.4	--	2.6	--	2.9	--	2.63	2.4	2.9	0.5
	Mean		2.84*		2.82*		2.78*	2.81* 2.81**			

*Waimea not included
**Waimea included

Table 16.-- Percent kernel recovery based on 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

		Harvest Dates									
		Sept.		Oct.		Nov.					
		Tree		Tree		Tree					
Orchard Ref. No.	Orchard Location	1	2	1	2	1	2	Mean	Min.	Max.	Range
1	Captain Cook	41.3	41.9	41.7	39.3	40.9	39.3	40.73	39.3	41.9	2.6
2	Haiku	46.2	44.6	46.5	46.0	44.9	44.4	45.42	44.4	46.5	2.1
3	Haleakala Exp. Fm.	44.4	42.2	46.1	43.5	45.6	43.7	44.24	42.2	46.1	3.9
4	Honakaa (Makai)	38.4	40.2	40.1	41.6	38.6	40.5	39.89	38.4	41.6	3.2
5	Honakaa (Mauka)	42.0	40.5	42.7	41.7	40.2	41.0	41.34	40.2	42.7	2.5
6	Honomalino	36.0	29.1	29.1	33.3	35.2	32.9	32.58	29.1	36.0	6.9
7	Kainaliu(Mauka)	39.4	42.2	41.4	41.1	38.9	39.6	40.41	38.9	42.2	3.3
8	Kainaliu(Makai)	38.4	36.3	38.1	37.3	38.0	36.7	37.47	36.3	38.4	2.1
9	Kalopa	38.6	39.8	42.0	40.5	40.4	40.6	40.31	38.6	42.0	3.4
10	Kau	39.3	40.8	40.1	41.4	40.4	41.6	40.60	39.3	41.6	2.3
11	Keaau	36.2	37.7	31.6	35.8	32.6	34.2	34.69	31.6	37.7	6.1
12	Keopuka	37.6	37.3	38.4	37.9	38.5	37.7	37.91	37.3	38.5	1.2
13	Kohala	42.9	42.2	44.3	43.9	43.5	42.0	43.13	42.0	44.3	2.3
14	Kolo (Makai)	24.4	29.6	24.0	31.1	25.5	28.8	27.22	24.0	31.1	7.1
15	Kolo (Mauka)	37.5	36.1	35.4	36.2	34.3	28.7	34.69	28.7	37.5	8.8
16	Kona Branch Sta.	42.8	42.9	44.8	43.6	45.3	45.0	44.05	42.8	45.3	2.5
17	Kurtistown	43.9	44.0	41.6	40.1	38.4	34.4	40.40	34.4	44.0	9.6
18	Malama Ki Exp. Fm.	34.3	33.4	37.2	37.1	31.2	29.3	33.75	29.3	37.2	7.9
19	Waiakea Exp. Fm.	40.7	40.1	40.7	41.5	39.1	39.0	40.16	39.0	41.5	2.5
20	Waimanalo Exp. Fm.	36.3	36.6	37.7	38.8	39.1	35.8	37.37	35.8	39.1	3.3
21	Waimea (Kamuela)	37.9	--	30.6	--	40.7	--	36.37	30.6	40.7	10.1
	Mean	38.94*		39.37*		38.14*		38.82* 38.76**			

*Waimea not included
**Waimea included

Table 17.-- Percent kernels showing stinkbug injury based on 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Harvest Dates: Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	0	0	0	0	0	0	0.0	0	0	0
2	Haiku	0	0	0	0	0	0	0.0	0	0	0
3	Haleakala Exp. Fm.	4	0	6	4	12	4	5.0	0	12	12
4	Honakaa (Makai)	0	0	0	0	0	0	0.0	0	0	0
5	Honakaa (Mauka)	0	0	0	0	0	4	0.7	0	4	4
6	Honomalino	0	0	6	2	2	0	1.7	0	6	6
7	Kainaliu(Mauka)	2	6	6	8	4	2	4.7	2	8	6
8	Kainaliu(Makai)	16	24	6	16	6	14	13.7	6	24	18
9	Kalopa	0	4	0	6	0	0	1.7	0	6	6
10	Kau	0	0	2	2	0	0	0.7	0	2	2
11	Keaau	0	0	0	0	0	0	0.0	0	0	0
12	Keopuka	0	2	0	2	0	2	1.0	0	2	2
13	Kohala	0	0	0	0	0	0	0.0	0	0	0
14	Kolo (Makai)	0	0	0	0	0	0	0.0	0	0	0
15	Kolo (Mauka)	0	0	0	0	0	0	0.0	0	0	0
16	Kona Branch Sta.	4	4	12	12	20	14	11.0	4	20	16
17	Kurtistown	0	0	0	0	0	0	0.0	0	0	0
18	Malama Ki Exp. Fm.	0	0	2	0	0	0	0.3	0	2	2
19	Waiakea Exp. Fm.	0	0	0	0	0	0	0.0	0	0	0
20	Waimanalo Exp. Fm.	24	42	38	30	30	16	30.0	16	42	26
21	Waimea (Kamuela)	2	--	0	--	0	--	0.7	0	2	2
	Mean	3.30*		4.00*		3.25*		3.52* 3.45**			

*Waimea not included
**Waimea included

Table 18.-- Percent grade 1 kernels based on counts from 50-nut samples of <u>Macadamia integrifolia</u> var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Harvest Dates: Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	68	81	84	54	80	58	70.8	54	84	30
2	Haiku	98	98	98	100	100	99	98.8	98	100	2
3	Haleakala Exp. Fm.	88	78	92	92	100	94	90.7	78	100	22
4	Honakaa (Makai)	83	95	92	96	97	98	93.5	83	98	15
5	Honakaa (Mauka)	95	89	93	91	92	92	92.0	89	95	6
6	Honomalino	73	57	44	74	56	66	61.7	44	74	30
7	Kainaliu (Mauka)	77	87	88	95	79	94	86.7	77	95	18
8	Kainaliu (Makai)	92	92	95	98	98	88	93.8	88	98	10
9	Kalopa	58	73	89	82	88	82	78.7	58	89	31
10	Kau	80	69	92	82	98	93	85.7	69	98	29
11	Keaau	79	88	52	61	42	54	62.7	42	88	46
12	Keopuka	96	90	98	86	98	86	92.3	86	98	12
13	Kohala	98	92	96	97	99	94	96.0	92	99	7
14	Kolo (Makai)	57	79	46	83	33	62	60.0	33	83	50
15	Kolo (Mauka)	98	95	96	88	88	90	92.5	88	98	10
16	Kona Branch Sta.	90	86	96	87	98	94	91.8	86	98	12
17	Kurtistown	93	94	92	71	52	41	73.8	41	94	53
18	Malama Ki Exp. Fm.	90	85	94	96	82	81	88.0	81	96	15
19	Waiakea Exp. Fm.	98	91	98	99	92	98	96.0	91	99	8
20	Waimanalo Exp. Fm.	90	96	96	100	98	97	96.2	90	100	10
21	Waimea (Kamuela)	47	--	55	--	77	--	59.7	47	77	30
	Mean	85.4*		86.6*		83.3*		85.1* 84.46**			

*Waimea not included
**Waimea included

Table 19.-- Percent grade 2 kernels based on counts from 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Harvest Dates Sept. Tree 1	2	Oct. Tree 1	2	Nov. Tree 1	2	Mean	Min.	Max.	Range
1	Captain Cook	20	9	6	24	8	20	14.5	6	24	18
2	Haiku	2	2	2	0	0	0	1.0	0	2	2
3	Haleakala Exp. Fm.	8	8	2	7	0	5	5.0	0	8	8
4	Honakaa (Makai)	13	5	8	4	3	2	5.8	2	13	11
5	Honakaa (Mauka)	5	5	5	6	8	3	5.3	3	8	5
6	Honomalino	24	30	10	17	43	25	24.8	10	43	33
7	Kainaliu(Mauka)	10	10	8	4	14	2	8.0	2	14	12
8	Kainaliu(Makai)	6	6	3	0	2	10	4.5	0	10	10
9	Kalopa	27	15	7	13	4	15	13.5	4	27	23
10	Kau	4	7	0	10	2	4	4.5	0	10	10
11	Keaau	15	6	16	26	32	32	21.2	6	32	26
12	Keopuka	2	2	2	4	2	3	2.5	2	4	2
13	Kohala	2	2	1	3	1	4	2.2	1	4	3
14	Kolo (Makai)	21	13	42	17	49	29	28.5	13	49	36
15	Kolo (Mauka)	2	5	2	12	12	8	6.8	2	12	10
16	Kona Branch Sta.	0	8	2	9	2	4	4.2	0	9	9
17	Kurtistown	7	6	2	7	18	12	8.7	2	18	16
18	Malama Ki Exp. Fm.	10	13	4	4	12	13	9.3	4	13	9
19	Waiakea Exp. Fm.	0	6	2	1	3	2	2.3	0	6	6
20	Waimanalo Exp. Fm.	4	1	3	0	2	3	2.2	0	4	4
21	Waimea (Kamuela)	33	--	32	--	16	--	27.0	16	33	17
	Mean	8.53*		7.38*		10.33*		8.74* 9.19**			

*Waimea not included
**Waimea included

Table 20.-- Percent grade 3 kernels based on counts from 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	12	10	10	22	12	22	14.7	10	22	12
2	Haiku	0	0	0	0	0	1	0.2	0	1	1
3	Haleakala Exp. Fm.	4	14	6	1	0	1	4.3	0	14	14
4	Honakaa (Makai)	4	0	0	0	0	0	0.7	0	4	4
5	Honakaa (Mauka)	0	6	2	3	0	5	2.7	0	6	6
6	Honomalino	3	13	46	9	1	9	13.5	1	46	45
7	Kainaliu (Mauka)	13	3	4	1	7	4	5.3	1	13	12
8	Kainaliu (Makai)	2	2	2	2	0	2	1.7	0	2	2
9	Kalopa	15	12	4	5	8	3	7.8	3	15	12
10	Kau	16	24	8	8	0	3	9.8	0	24	24
11	Keaau	6	6	32	13	26	14	16.2	6	32	26
12	Keopuka	2	8	0	10	0	11	5.2	0	11	11
13	Kohala	0	6	3	0	0	2	1.8	0	6	6
14	Kolo (Makai)	22	8	12	0	18	9	11.5	0	22	22
15	Kolo (Mauka)	0	0	2	0	0	2	0.7	0	2	2
16	Kona Branch Sta.	10	6	2	4	0	2	4.0	0	10	10
17	Kurtistown	0	0	6	22	30	47	17.5	0	47	47
18	Malama Ki Exp. Fm.	0	2	2	0	6	6	2.7	0	6	6
19	Waiakea Exp. Fm.	2	3	0	0	5	0	1.7	0	5	5
20	Waimanalo Exp. Fm.	6	3	1	0	0	0	1.7	0	6	6
21	Waimea (Kamuela)	20	--	13	--	7	--	13.3	7	20	13
	Mean	6.08*		6.05*		6.40*		6.18* 6.35**			

*Waimea not included
**Waimea included

Table 21.-- Shell width (1/64th inch) based on 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Harvest Dates Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	62.7	63.1	64.4	63.2	64.8	62.2	63.40	62.2	64.8	2.6
2	Haiku	63.4	61.6	60.2	61.7	61.2	63.3	61.88	60.2	63.4	3.2
3	Haleakala Exp. Fm.	62.7	63.3	62.5	62.8	62.1	62.8	62.69	62.1	63.3	1.2
4	Honakaa (Makai)	61.9	61.3	61.3	60.5	64.1	60.7	61.63	60.5	64.1	3.6
5	Honakaa (Mauka)	64.6	65.0	63.7	63.2	62.8	62.0	63.52	62.0	65.0	3.0
6	Honomalino	61.7	58.8	57.7	58.9	59.8	59.5	59.38	57.7	61.7	4.0
7	Kainaliu(Mauka)	63.5	64.2	64.1	64.0	63.7	65.3	64.13	63.5	65.3	1.8
8	Kainaliu(Makai)	62.2	63.0	61.9	63.5	61.4	62.5	62.43	61.4	63.5	2.1
9	Kalopa	62.2	63.2	64.1	63.2	61.6	61.0	62.53	61.0	64.1	3.1
10	Kau	59.3	60.8	59.2	60.3	59.1	61.2	60.00	59.1	61.2	2.1
11	Keaau	63.6	62.5	64.3	61.3	65.6	63.6	63.48	61.3	65.6	4.3
12	Keopuka	66.2	63.4	62.6	61.8	64.3	60.8	63.18	60.8	66.2	5.4
13	Kohala	62.1	62.4	62.6	60.9	62.5	62.4	62.13	60.9	62.6	1.7
14	Kolo (Makai)	57.7	60.5	56.5	61.4	59.7	59.2	59.17	56.5	61.4	4.9
15	Kolo (Mauka)	63.0	62.3	64.0	63.5	63.1	64.7	63.43	62.3	64.7	2.4
16	Kona Branch Sta.	63.7	64.6	62.5	63.6	63.3	63.3	63.48	62.5	64.6	2.1
17	Kurtistown	63.3	60.7	63.8	61.8	60.9	63.0	62.24	60.7	63.8	3.1
18	Malama Ki Exp. Fm.	59.7	58.4	60.0	59.3	62.5	60.6	60.09	58.4	62.5	4.1
19	Waiakea Exp. Fm.	60.4	59.9	58.1	57.8	58.7	56.5	58.57	56.5	60.4	3.9
20	Waimanalo Exp. Fm.	62.3	61.3	61.0	61.7	62.5	61.9	61.77	61.0	62.5	1.5
21	Waimea (Kamuela)	60.2	--	60.1	--	61.7	--	60.69	60.1	61.7	1.6
	Mean	62.15*		61.72*		62.00*		61.96* 61.93**			

*Waimea not included
**Waimea included

Table 22.-- Shell length (1/64th inch) based on 50-nut samples of <u>Macadamia</u> <u>integrifolia</u> var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Harvest Dates: Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	62.1	62.2	63.7	62.6	64.4	62.0	62.82	62.0	64.4	2.4
2	Haiku	62.1	60.7	59.0	60.5	60.3	62.5	60.84	59.0	62.5	3.5
3	Haleakala Exp. Fm.	62.2	62.5	61.5	62.0	61.3	62.1	61.94	61.3	62.5	1.2
4	Honakaa (Makai)	61.4	60.7	60.8	60.0	64.0	61.0	61.31	60.0	64.0	4.0
5	Honakaa (Mauka)	63.8	64.4	63.3	63.1	62.5	61.6	63.11	61.6	64.4	2.8
6	Honomalino	62.1	60.1	59.1	60.3	60.8	60.3	60.45	59.1	62.1	3.0
7	Kainaliu(Mauka)	62.6	63.1	63.1	63.0	63.0	64.1	63.15	62.6	64.1	1.5
8	Kainaliu(Makai)	61.5	62.7	61.9	63.4	61.3	62.7	62.22	61.3	63.4	2.1
9	Kalopa	61.6	62.5	63.4	62.2	61.1	60.5	61.88	60.5	63.4	2.9
10	Kau	58.5	60.0	59.0	59.8	59.2	60.6	59.51	58.5	60.6	2.1
11	Keaau	63.7	62.4	64.9	61.5	65.8	63.8	63.67	61.5	65.8	4.3
12	Keopuka	65.8	62.9	62.0	61.3	63.3	60.6	62.64	60.6	65.8	5.2
13	Kohala	61.3	61.1	61.6	60.2	61.4	61.4	61.17	60.2	61.6	1.4
14	Kolo (Makai)	58.7	61.0	58.2	62.4	60.9	60.1	60.21	58.2	62.4	4.2
15	Kolo (Mauka)	63.0	62.1	64.1	63.6	63.3	65.4	63.56	62.1	65.4	3.3
16	Kona Branch Sta.	62.7	63.1	61.5	62.4	61.8	61.9	62.23	61.5	63.1	1.6
17	Kurtistown	62.6	60.0	62.9	61.1	60.5	62.4	61.57	60.0	62.9	2.9
18	Malama Ki Exp. Fm.	60.0	58.3	60.0	59.4	62.9	61.0	60.25	58.3	62.9	4.6
19	Waiakea Exp. Fm.	59.5	59.2	57.8	57.3	58.5	56.3	58.10	56.3	59.5	3.2
20	Waimanalo Exp. Fm.	61.5	60.7	60.9	61.1	61.9	61.9	61.34	60.7	61.9	1.2
21	Waimea (Kamuela)	59.7	--	59.7	--	61.4	--	60.25	59.7	61.4	1.7
	Mean	61.65*		61.39*		61.75*		61.60* 61.57**			

*Waimea not included
**Waimea included

Table 23.-- Shell thickness at the base (1/64th inch) based on 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Harvest Dates: Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	8.9	8.1	9.1	9.2	8.8	9.1	8.85	8.1	9.2	1.1
2	Haiku	8.5	8.6	7.9	8.2	8.1	8.5	8.31	7.9	8.6	0.7
3	Haleakala Exp. Fm.	8.7	9.0	8.7	8.6	8.3	8.5	8.62	8.3	9.0	0.7
4	Honakaa (Makai)	10.0	9.8	9.3	8.9	9.8	8.7	9.40	8.7	10.0	1.3
5	Honakaa (Mauka)	9.7	10.9	9.2	9.9	9.3	8.9	9.65	8.9	10.9	2.0
6	Honomalino	10.3	11.3	10.5	9.5	10.1	9.9	10.27	9.5	11.3	1.8
7	Kainaliu (Mauka)	9.8	9.3	9.6	9.6	9.6	9.9	9.64	9.3	9.9	0.6
8	Kainaliu (Makai)	9.7	10.3	9.7	10.1	10.0	10.0	9.97	9.7	10.3	0.6
9	Kalopa	10.0	10.1	10.0	9.3	9.1	9.3	9.63	9.1	10.1	1.0
10	Kau	9.3	8.7	8.7	8.2	9.1	8.5	8.75	8.2	9.3	1.1
11	Keaau	11.1	10.4	10.8	10.4	11.5	11.0	10.86	10.4	11.5	1.1
12	Keopuka	11.1	10.3	9.7	9.6	10.2	9.6	10.10	9.6	11.1	1.5
13	Kohala	9.5	9.8	9.0	8.7	8.9	9.5	9.23	8.7	9.8	1.1
14	Kolo (Makai)	12.6	11.5	11.8	11.0	11.6	11.2	11.63	11.0	12.6	1.6
15	Kolo (Mauka)	10.7	10.8	10.7	10.3	10.8	13.9	11.18	10.3	13.9	3.6
16	Kona Branch Sta.	8.4	9.0	8.6	8.8	8.3	8.4	8.58	8.3	9.0	0.7
17	Kurtistown	9.4	9.3	9.5	9.0	8.8	9.7	9.29	8.8	9.7	0.9
18	Malama Ki Exp. Fm.	10.7	10.4	10.0	10.1	11.8	11.9	10.83	10.0	11.9	1.9
19	Waiakea Exp. Fm.	9.8	9.8	8.9	8.8	9.4	9.0	9.27	8.8	9.8	1.0
20	Waimanalo Exp. Fm.	10.5	10.6	10.0	9.5	10.1	11.1	10.31	9.5	11.1	1.6
21	Waimea (Kamuela)	9.5	--	8.7	--	9.0	--	9.06	8.7	9.5	0.8
	Mean	9.92*		9.48*		9.75*		9.72* 9.70**			

*Waimea not included
**Waimea included

Table 24. -- Shell thickness at the side (1/64th inch) based on 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Sept. Tree 1	Sept. Tree 2	Oct. Tree 1	Oct. Tree 2	Nov. Tree 1	Nov. Tree 2	Mean	Min.	Max.	Range
1	Captain Cook	5.9	6.1	6.3	6.2	6.5	6.4	6.24	5.9	6.5	0.6
2	Haiku	5.6	5.6	5.4	5.6	5.6	5.8	5.59	5.4	5.8	0.4
3	Haleakala Exp. Fm.	5.6	5.7	5.5	5.8	5.9	5.8	5.73	5.5	5.9	0.4
4	Honakaa (Makai)	6.2	6.0	6.0	6.1	6.7	6.4	6.22	6.0	6.7	0.7
5	Honakaa (Mauka)	6.1	6.3	6.3	6.3	6.6	6.4	6.33	6.1	6.6	0.5
6	Honomalino	7.1	7.6	7.2	6.9	7.3	7.4	7.25	6.9	7.6	0.7
7	Kainaliu (Mauka)	6.4	6.2	6.1	6.3	6.8	6.8	6.44	6.1	6.8	0.7
8	Kainaliu (Makai)	6.3	6.6	6.7	6.9	6.6	7.0	6.67	6.3	7.0	0.7
9	Kalopa	6.2	6.4	6.3	6.1	6.5	6.4	6.31	6.1	6.5	0.4
10	Kau	5.9	5.7	6.0	5.7	6.4	6.2	6.00	5.7	6.4	0.7
11	Keaau	6.9	6.4	7.2	6.6	7.4	7.1	6.95	6.4	7.4	1.0
12	Keopuka	6.7	6.4	6.9	6.7	6.8	6.6	6.68	6.4	6.9	0.5
13	Kohala	5.7	6.0	5.9	6.1	6.2	6.2	5.99	5.7	6.2	0.5
14	Kolo (Makai)	7.8	7.6	8.5	8.0	8.6	8.3	8.12	7.6	8.6	1.0
15	Kolo (Mauka)	6.6	7.0	7.4	6.9	7.5	8.5	7.32	6.6	8.5	1.9
16	Kona Branch Sta.	5.7	6.2	5.9	6.0	5.9	6.1	5.96	5.7	6.2	0.5
17	Kurtistown	6.0	5.2	6.7	6.4	6.0	6.7	6.15	5.2	6.7	1.5
18	Malama Ki Exp. Fm.	7.3	7.1	6.7	7.0	7.6	8.4	7.35	6.7	8.4	1.7
19	Waiakea Exp. Fm.	6.0	6.0	6.3	6.1	6.3	6.4	6.16	6.0	6.4	0.4
20	Waimanalo Exp. Fm.	7.1	6.7	6.7	6.5	7.1	7.2	6.88	6.5	7.2	0.7
21	Waimea (Kamuela)	6.0	--	6.1	--	6.3	--	6.11	6.0	6.3	0.3
	Mean		6.35*		6.44*		6.76*	6.52* 6.51**			

*Waimea not included
**Waimea included

APPENDIX

B

Table 25. -- Nut weight, in grams. Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Class Limits		Frequency Observed (f_i)	Frequency Expected (F_i)	$\frac{(f_i - F_i)}{F_i}$
...... 5.79	**	2	1.51	0.16
5.80 - 5.99	*	1	1.76	0.33
6.00 - 6.19	******	6	3.20	2.45
6.20 - 6.39	******	6	5.31	0.09
6.40 - 6.59	******	6	7.95	0.48
6.60 - 6.79	**********	10	10.81	0.06
6.80 - 6.99	********	8	13.35	2.14
7.00 - 7.19	****************	16	15.02	0.06
7.20 - 7.39	*****************	17	15.22	0.21
7.40 - 7.59	****************	16	14.03	0.28
7.60 - 7.79	*************	13	11.78	0.13
7.80 - 7.99	***********	11	8.90	0.50
8.00 - 8.19	*****	5	6.15	0.22
8.20 - 8.39	**	2	3.84	0.88
8.40 - 8.59	***	3	2.18	0.31
8.60	*	1	1.99	0.49
		123	123.00	8.79

d.f. = 16 - 3 = 13 $X^2 = 8.79$ $.90 > P > 0.75$

Table 26. -- Kernel weight, in grams. Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Class Limits		Frequency: Observed (f_i)		Frequency: Expected (F_i)		$\frac{(f_i - F_i)}{F_i}$
...... 1.49	**	2		.16		
1.50 - 1.64		0		.33		
1.65 - 1.79	***	3	5	.79	3.01	1.32
1.80 - 1.94		0		1.73		
1.95 - 2.09	***	3		3.39		0.04
2.10 - 2.24	****	4		5.87		0.60
2.25 - 2.39	******	6		9.08		1.04
2.40 - 2.54	************	12		12.51		0.02
2.55 - 2.69	***************	15		15.30		0.01
2.70 - 2.84	*****************	17		16.70		0.01
2.85 - 2.99	*****************	17		16.19		0.04
3.00 - 3.14	*************	13		14.00		0.07
3.15 - 3.29	************	12		10.74		0.15
3.30 - 3.44	******************	18		7.35		15.43
3.45	*	1		8.86		6.97
		123		123.00		25.70

d.f. = 12 - 3 = 9 $\quad X^2 = 25.70 \quad P < 0.005$

Table 27. -- Percent kernel recovery. Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Class Limits		Frequency Observed (f_i)	Frequency Expected (F_i)	$\frac{(f_i - F_i)}{F_i}$
.... 28.49	***	3	1.81	0.78
28.50 - 29.99	******	6	2.07	7.46
30.00 - 31.49	***	3	3.73	0.14
31.50 - 32.99	***	3	6.03	1.52
33.00 - 34.49	******	6	8.88	0.93
34.50 - 35.99	****	4	11.81	5.16
36.00 - 37.49	************	12	14.19	0.34
37.50 - 38.99	*******************	19	15.44	0.82
39.00 - 40.49	*******************	19	15.21	0.94
40.50 - 41.99	*******************	19	13.57	2.17
42.00 - 43.49	**********	10	10.91	0.08
43.50 - 44.99	************	12	7.93	2.09
45.00 - 46.49	******	6	5.23	0.11
46.50	*	1	6.20	4.36
		123	123.01	26.90

d.f. = 14 - 3 = 11 $X^2 = 26.90$ $P \cong 0.005$

Table 28. -- Percent grade 1 kernels. Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Class Limits		Frequency Observed (f_i)		Frequency Expected (F_i)		$\frac{(f_i - F_i)}{F_i}$
.... 39	*	1	6	0.28	1.68	11.11
40 - 44	***	3		0.45		
45 - 49	**	2		0.95		
50 - 54	****	4		1.94		2.19
55 - 59	******	6		3.41		1.97
60 - 64	**	2		5.74		2.44
65 - 69	***	3		8.28		3.37
70 - 74	****	4		11.46		4.86
75 - 79	******	6		13.55		4.21
80 - 84	***********	11		15.44		1.28
85 - 89	***************	15		15.44		0.01
90 - 94	***************************	27		13.55		13.35
95 - 99	***********************************	35		11.46		48.35
100	****	4		21.05		13.81
		123		123.00		106.95

d.f. = 12 - 3 = 9 $\chi^2 = 106.95$ $P < 0.005$

Table 29. -- Percent grade 2 kernels. Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Class Limits		Frequency Observed (f_i)	Frequency Expected (F_i)	$\frac{(f_i - F_i)}{F_i}$
.... 0	*********	9	23.33	8.80
1 - 3	**********************************	34	11.43	44.57
4 - 6	************************	24	13.56	8.04
7 - 9	***************	15	14.76	0.00
10 - 12	**********	10	14.56	1.43
13 - 15	*********	9	13.21	1.34
16 - 18	*****	5	10.86	3.16
19 - 21	***	3	8.19	3.29
22 - 24	**	2	5.63	2.34
25 - 27	***	3	3.53	0.08
28 - 30	**	2	2.02	0.00
31 - 33	****	4 } 7	1.07 } 1.92	13.44
34	***	3	0.85	
		123	123.00	86.49

d.f. = 12 - 3 = 9 $\qquad X^2 = 86.49 \qquad P < 0.005$

Table 30. -- Percent grade 3 kernels. Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Class Limits		Frequency Observed (f_i)		Frequency Expected (F_i)		$\frac{(f_i - F_i)^{}}{F_i}$
.... 0	************************************	36		30.77		0.89
1 - 3	*****************************	29		14.87		13.43
4 - 6	*******************	19		16.69		0.32
7 - 9	**********	10		16.59		2.62
10 - 12	*********	9		14.65		2.18
13 - 15	*******	7		11.50		1.76
16 - 18	**	2		8.01		4.51
19 - 21	*	1		4.96		3.16
22 - 24	*****	5		2.72		1.91
25 - 27	*	1	5	1.34	2.24	3.40
28 - 30	*	1		0.57		
31 - 33	*	1		0.22		
34	**	2		0.11		
		123		123.00		34.18

d.f. = 10 - 3 = 7 $X^2 = 34.18$ $P < 0.005$

Table 31. -- Shell width (1/64th inch). Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Class Limits		Frequency Observed (f_i)	Frequency Expected (F_i)	$\frac{(f_i - F_i)}{F_i}$
.... 57.49	**	2	1.34	0.32
57.50 - 58.24	****	4	2.14	1.62
58.25 - 58.99	****	4	4.45	0.05
59.00 - 59.74	********	8	7.98	0.00
59.75 - 60.49	*********	9	12.29	0.88
60.50 - 61.24	************	12	16.33	1.15
61.25 - 61.99	******************	18	18.73	0.03
62.00 - 62.74	********************	20	18.43	0.13
62.75 - 63.49	**********************	22	15.71	2.52
63.50 - 64.24	*************	13	11.46	0.21
64.24 - 64.99	********	8	7.25	0.08
65.00 - 65.74	**	2	3.94	0.95
65.75	*	1	2.95	1.29
		123	123.00	9.23

d.f. = 13 - 3 = 10 $\quad X^2 = 9.23$ $\quad P \cong 0.50$

Table 32. -- Shell length (1/64th inch). Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Class Limits		Frequency Observed (f_i)		Frequency Expected (F_i)		$\frac{(f_i - F_i)}{F_i}$
.... 56.74	*	1	2	0.33	1.15	0.63
56.75 - 57.49	*	1		0.82		
57.50 - 58.24	**	2		2.24		0.03
58.25 - 58.99	****	4		5.08		0.23
59.00 - 59.74	*********	9		9.57		0.03
59.75 - 60.49	*************	13		14.91		0.24
60.50 - 61.24	******************	18		19.48		0.11
61.25 - 61.99	**********************	22		21.06		0.04
62.00 - 62.74	************************	24		18.97		1.33
62.75 - 63.49	***************	15		14.17		0.05
63.50 - 64.24	********	8		8.84		0.08
64.25 - 64.99	***	3		4.58		0.55
65.00 - 65.74	*	1	3	1.97	2.95	0.00
65.75	**	2		0.98		
		123		123.00		3.32

d.f. = 12 - 3 = 9 $\qquad X^2 = 3.32 \qquad$ P = 0.95

Table 33. -- Shell thickness at the base (1/64th inch). Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of <u>Macadamia integrifolia</u> var. 'Keauhou'

Class Limits		Frequency Observed (f_i)	Frequency Expected (F_i)	$\frac{(f_i - F_i)}{F_i}$
.... 7.99	*	1	5.95	4.12
8.00 - 8.49	*********	9	8.81	0.00
8.50 - 8.99	************************	24	15.42	4.77
9.00 - 9.49	***********************	23	21.46	0.11
9.50 - 9.99	************************	24	23.62	0.01
10.00 - 10.49	******************	18	20.60	0.33
10.50 - 10.99	**********	10	14.29	1.29
11.00 - 11.49	*******	7	7.84	0.09
11.50 - 11.99	*****	5	3.42	0.73
12.00 - 12.49		0	1.18	
12.50 - 12.99	*	1 } 2	0.32 } 1.59	0.11
13.00	*	1	0.09	
		123	123.00	11.56

d.f. = 10 - 3 = 7 $\chi^2 = 11.56$ $0.25 > P > 0.10$

Table 34. -- Shell thickness at the side (1/64th inch). Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Class Limits		Frequency Observed (f_i)	Frequency Expected (F_i)	$(f_i - F_i)$ / F_i
...... 5.19	*	1	3.42	1.71
5.20 - 5.39	*	1	3.03	1.36
5.40 - 5.59	****	4	4.82	0.69
5.60 - 5.79	*******	7	7.11	0.00
5.80 - 5.99	**************	14	9.61	2.01
6.00 - 6.19	*****************	17	11.94	2.14
6.20 - 6.39	*******************	19	13.60	2.14
6.40 - 6.59	************	12	14.23	0.35
6.60 - 6.79	*************	13	13.76	0.04
6.80 - 6.99	**********	10	12.16	0.38
7.00 - 7.19	******	6	9.91	1.54
7.20 - 7.39	*******	7	7.40	0.02
7.40 - 7.59	**	2	5.07	1.86
7.60 - 7.79	****	4	3.21	0.19
7.80 - 7.99	*	1	1.87	0.40
8.00 - 8.19		0	1.00	
8.20 - 8.39	**	2 } 5	0.49 } 1.85	5.30
8.40 - 8.59	**	2	0.22	
8.60	*	1	0.14	
		123	123.00	20.13

d.f. = 16 - 3 = 13 $\qquad X^2 = 20.13 \qquad 0.10 > P > 0.05$

Table 35. -- Percent grade 1 (angle = arcsin $\sqrt{\%}$). Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Class Limits		Frequency: Observed (f_i)	Frequency: Expected (F_i)	$\frac{(f_i - F_i)}{F_i}$
...... 39.9	**	2	1.09	0.76
40.0 - 44.9	****	4	1.98	2.06
45.0 - 49.9	**********	10	4.23	7.87
50.0 - 54.9	***	3	8.08	3.19
55.0 - 59.9	******	6	12.48	3.36
60.0 - 64.9	**************	14	17.26	0.62
65.0 - 69.9	****************	16	18.82	0.42
70.0 - 74.9	***********************	23	19.35	0.69
75.0 - 79.9	*******************	19	15.73	0.68
80.0 - 84.9	**********************	22	11.43	9.77
85.0	****	4	12.55	5.82
		123	123.00	35.24

d.f. = 11 - 3 = 8 $\quad X^2 = 35.24 \quad P < 0.005$

Table 36. -- Percent grade 2 (angle = arcsin $\sqrt{\%}$). Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of *Macadamia integrifolia* var. 'Keauhou'

Class Limits		Frequency Observed (f_i)	Frequency Expected (F_i)	$(f_i - F_i)$ / F_i
...... 4.9	*********	9	16.21	3.21
5.0 - 7.9	****	4	9.93	3.54
8.0 - 10.9	******************************	30	12.77	23.25
11.0 - 13.9	*****************	17	14.87	0.31
14.0 - 16.9	********************	20	15.65	1.21
17.0 - 19.9	********	8	14.85	3.16
20.0 - 22.9	*************	13	12.74	0.01
23.0 - 25.9	*****	5	9.88	2.41
26.0 - 28.9	***	3	6.91	2.21
29.0 - 31.9	*****	5	4.39	0.08
32.0 - 34.9	*****	5	2.51	2.47
35.0	****	4	2.30	1.26
		123	123.00	43.12

d.f. = 12 - 3 = 9 $\quad X^2 = 43.12 \quad P < 0.005$

Table 37. -- Percent grade 3 (angle = arcsin $\sqrt{\%}$). Frequency distribution and chi-square goodness of fit test based on means of 50-nut samples of Macadamia integrifolia var. 'Keauhou'

Class Limits		Frequency Observed (f_i)	Frequency Expected (F_i)	$\frac{(f_i - F_i)}{F_i}$
...... 4.9	************************************	36	32.60	0.35
5.0 - 7.9	******	6	13.14	3.88
8.0 - 10.9	***********************	23	14.54	4.92
11.0 - 13.9	*********	9	14.65	2.18
14.0 - 16.9	*****************	17	13.43	0.95
17.0 - 19.9	********	8	11.35	0.99
20.0 - 22.9	***********	11	8.71	0.60
23.0 - 25.9	**	2	6.10	2.76
26.0 - 28.9	*****	5	3.92	0.30
29.0 - 31.9	**	2	2.30	0.04
32.0 - 34.9	**	2	1.23	0.48
35.0	**	2	1.03	0.91
		123	123.00	18.36

d.f. = 12 - 3 = 9 $\chi^2 = 18.36$ $0.05 > P > 0.025$

APPENDIX

C

Table 38. -- Analysis of variance of combined locations for nut weight, in grams, of *Macadamia integrifolia* var. 'Keauhou'

Grand Mean = 7.23

No.	Location	Mean	Duncan's Multiple Range 5%	1%
19	Waiakea Exp. Fm.	6.19	a	a
10	Kau (Hawaii Orchards)	6.35	ab	ab
06	Honomalino	6.42	abc	abc
14	Kolo (Makai)	6.71	abcd	abcd
18	Malama Ki Exp. Fm.	6.83	abcde	abcde
17	Kurtistown	6.98	bcdef	abcdef
04	Honakaa (Makai)	7.11	cdefg	abcdef
02	Haiku (Taketa)	7.14	defg	abcdef
13	Kohala (Bond)	7.28	defgh	bcdef
03	Haleakala Exp. Fm.	7.31	defgh	bcdef
20	Waimanalo Exp. Fm.	7.31	defgh	bcdef
09	Kalopa (Ferreira)	7.36	defgh	cdef
01	Captain Cook	7.42	defgh	def
08	Kainaliu (Makai)	7.52	efgh	def
11	Keaau (Royal Haw.)	7.61	fgh	def
16	Kona Branch Sta.	7.64	fgh	def
12	Keopuka (Fukunaga)	7.69	fgh	def
05	Honakaa (Mauka)	7.83	gh	ef
07	Kainaliu (Mauka)	7.89	h	f
15	Kolo (Mauka)	7.95	h	f

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	1.589	5.80**
Trees within loc. (Error A)	20	0.274	
Harvest Dates	2	0.220	2.06
Loc. X Dates	38	0.186	1.74*
Error B	40	0.107	

Table 39. -- Analysis of variance of combined locations for kernel weight, in grams, of <u>Macadamia integrifolia</u> var. 'Keauhou'

Grand Mean = 2.81

No.	Location	Mean	Duncan's Multiple Range 5%	1%
14	Kolo (Makai)	1.84	a	a
06	Honomalino	2.10	ab	ab
18	Malama Ki Exp. Sta.	2.30	bc	abc
19	Waiakea Exp. Fm.	2.49	cd	bcd
10	Kau (Hawaii Orchards)	2.58	cde	cde
11	Keaau (Royal Haw.)	2.64	cdef	cdef
20	Waimanalo Exp. Fm.	2.73	defg	cdefg
15	Kolo (Mauka)	2.75	defg	cdefg
08	Kainaliu (Makai)	2.82	defgh	defg
17	Kurtistown	2.83	defghi	defg
04	Honakaa (Makai)	2.83	defghi	defg
12	Keopuka (Fukunaga)	2.92	efghij	defgh
09	Kalopa (Ferreira)	2.97	fghij	defgh
01	Captain Cook	3.02	ghijk	efgh
13	Kohala (Bond)	3.14	hijk	fgh
07	Kainaliu (Mauka)	3.19	ijk	gh
03	Haleakala Exp. Fm.	3.23	jk	gh
05	Honakaa (Mauka)	3.24	jk	gh
02	Haiku (Taketa)	3.24	jk	gh
16	Kona Branch Sta.	3.36	k	h

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	0.9780	13.36**
Trees within loc. (Error A)	20	0.0732	
Harvest Dates	2	0.0354	1.29
Loc. X Dates	38	0.0503	1.84*
Error B	40	0.0274	

Table 40. -- Analysis of variance of combined locations for percent kernel recovery of Macadamia integrifolia var. 'Keauhou'

Grand Mean = 38.82

No.	Location	Mean	Duncan's Multiple Range 5%	1%
14	Kolo (Makai)	27.22	a	a
06	Honomalino	32.58	b	b
18	Malama Ki Exp. Fm.	33.75	b	bc
15	Kolo (Mauka)	34.69	b	bcd
11	Keaau (Royal Haw.)	34.69	b	bcd
20	Waimanalo Exp. Fm.	37.37	c	cde
08	Kainaliu (Makai)	37.47	cd	cde
12	Keopuka (Fukunaga)	37.91	cde	de
04	Honakaa (Makai)	39.89	cdef	ef
19	Waiakea Exp. Fm.	40.16	cdef	efg
09	Kalopa (Ferreira)	40.31	defg	efgh
17	Kurtistown	40.40	efg	efgh
07	Kainaliu (Mauka)	40.41	efg	efgh
10	Kau (Hawaii Orchards)	40.60	efg	efgh
01	Captain Cook	40.73	efg	efgh
05	Honakaa (Mauka)	41.34	fg	efgh
13	Kohala (Bond)	43.13	gh	fghi
16	Kona Branch Sta.	44.05	h	ghi
03	Haleakala Exp. Fm.	44.24	h	hi
02	Haiku (Taketa)	45.42	h	i

No.	Harvest Date	Mean	Duncan's Multiple Range 5%	1%
3	Nov.	38.14	a	a
1	Sept.	38.94	b	b
2	Oct.	39.37	b	b

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	120.077	26.24**
Trees with loc. (Error A)	20	4.576	
Harvest Dates	2	15.485	8.98**
Loc. X Dates	38	4.406	2.56**
Error B	40	1.724	

Table 41. -- Analysis of variance of combined locations for percent grade 1 kernels (by count) of *Macadamia integrifolia* var. 'Keauhou'

Grand Mean = 85.08

No.	Location	Mean	Duncan's Multiple Range 5%	Duncan's Multiple Range 1%
14	Kolo (Makai)	60.00	a	a
06	Honomalino	61.67	a	a
11	Keaau (Royal Haw.)	62.67	a	a
01	Captain Cook	70.83	ab	ab
17	Kurtistown	73.83	abc	abc
09	Kalopa (Ferreira)	78.67	bcd	abcd
10	Kau (Hawaii Orchards)	85.67	cde	bcd
07	Kainaliu (Mauka)	86.67	cde	bcd
18	Malama Ki Exp. Fm.	88.00	cde	bcd
03	Haleakala Exp. Fm.	90.67	de	bcd
16	Kona Branch Sta.	91.83	de	bcd
05	Honakaa (Mauka)	92.00	de	bcd
12	Keopuka (Fukunaga)	92.33	de	cd
15	Kolo (Mauka)	92.50	de	cd
04	Honakaa (Makai)	93.50	de	cd
08	Kainaliu (Makai)	93.83	de	cd
13	Kohala (Bond)	96.00	e	d
19	Waiakea Exp. Fm.	96.00	e	d
20	Waimanalo Exp. Fm.	96.17	e	d
02	Haiku (Taketa)	98.83	e	d

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	944.833	7.30**
Trees within loc. (Error A)	20	129.433	
Harvest Dates	2	111.908	2.70
Loc. X Dates	38	152.856	3.68**
Error B	40	41.508	

Table 42. -- Analysis of variance of combined locations for percent grade 2 kernels (by count) of _Macadamia integrifolia_ var. 'Keauhou'

Grand Mean = 8.74

No.	Location	Mean	Duncan's Multiple Range 5%	Duncan's Multiple Range 1%
02	Haiku (Taketa)	1.00	a	a
13	Kohala (Bond)	2.17	a	ab
20	Waimanalo Exp. Fm.	2.17	a	ab
19	Waiakea Exp. Fm.	2.33	a	ab
12	Keopuka (Fukunaga)	2.50	a	ab
16	Kona Branch Sta.	4.17	a	abc
10	Kau (Hawaii Orchards)	4.50	a	abc
08	Kainaliu (Makai)	4.50	a	abc
03	Haleakala Exp. Fm.	5.00	a	abc
05	Honakaa (Mauka)	5.33	ab	abc
04	Honakaa (Makai)	5.83	ab	abc
15	Kolo (Mauka)	6.83	abc	abc
07	Kainaliu (Mauka)	8.00	abc	abc
17	Kurtistown	8.67	abc	abc
18	Malama Ki Exp. Fm.	9.33	abc	abc
09	Kalopa (Ferreira)	13.50	bcd	bcd
01	Captain Cook	14.50	cd	cde
11	Keaau (Royal Haw.)	21.17	de	def
06	Honomalino	24.83	e	ef
14	Kolo (Makai)	28.50	e	f

No.	Harvest Date	Mean	Duncan's Multiple Range 5%	Duncan's Multiple Range 1%
2	Oct.	7.38	a	a
1	Sept.	8.53	ab	a
3	Nov.	10.33	b	a

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	373.096	9.99**
Trees within loc. (Error A)	20	37.342	
Harvest Dates	2	88.433	3.59*
Loc. X Dates	38	46.547	1.89
Error B	40	24.642	

Table 43. -- Analysis of variance of combined locations for percent grade 3 kernels (by count) of Macadamia integrifolia var. 'Keauhou'

Grand Mean = 6.18

No.	Location	Mean	Duncan's Multiple Range 5%	1%
02	Haiku (Taketa)	0.17	a	a
04	Honakaa (Makai)	0.67	ab	ab
15	Kolo (Mauka)	0.67	ab	ab
08	Kainaliu (Makai)	1.67	ab	ab
19	Waiakea Exp. Fm.	1.67	ab	ab
20	Waimanalo Exp. Fm.	1.67	ab	ab
13	Kohala (Bond)	1.83	ab	ab
05	Honakaa (Mauka)	2.67	abc	abc
18	Malama Ki Exp. Fm.	2.67	abc	abc
16	Kona Branch Sta.	4.00	abc	abcd
03	Haleakala Exp. Fm.	4.33	abcd	abcd
12	Keopuka (Fukunaga)	5.17	abcd	abcde
07	Kainaliu (Mauka)	5.33	abcd	abcde
09	Kalopa (Ferreira)	7.83	abcde	abcde
10	Kau (Hawaii Orchards)	9.83	bcdef	abcde
14	Kolo (Makai)	11.50	cdef	abcde
06	Honomalino	13.50	def	bcde
01	Captain Cook	14.67	ef	cde
11	Keaau (Royal Haw.)	16.17	ef	de
17	Kurtistown	17.50	f	e

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	192.447	4.24**
Trees within loc. (Error A)	20	45.408	
Harvest Dates	2	1.525	0.05
Loc. X Dates	38	85.507	3.04**
Error B	40	28.158	

Table 44. -- Analysis of variance of combined locations for shell width (1/64th inch) of Macadamia integrifolia var. 'Keauhou'

Grand Mean = 61.96

No.	Location	Mean	Duncan's Multiple Range 5%	1%
19	Waiakea Exp. Fm.	58.57	a	a
14	Kolo (Makai)	59.17	a	ab
06	Honomalino	59.38	a	ab
10	Kau (Hawaii Orchards)	60.00	ab	abc
18	Malama Ki Exp. Fm.	60.09	ab	abc
04	Honakaa (Makai)	61.63	bc	bcd
20	Waimanalo Exp. Fm.	61.77	bc	bcd
02	Haiku (Taketa)	61.88	bc	bcd
13	Kohala (Bond)	62.13	cd	cd
17	Kurtistown	62.24	cd	cd
08	Kainaliu (Makai)	62.43	cd	cd
09	Kalopa (Ferreira)	62.53	cd	cd
03	Haleakala Exp. Fm.	62.69	cd	cd
12	Keopuka (Fukunaga)	63.18	cd	d
01	Captain Cook	63.40	cd	d
15	Kolo (Mauka)	63.43	cd	d
11	Keaau (Royal Haw.)	63.48	cd	d
16	Kona Branch Sta.	63.48	cd	d
05	Honakaa (Mauka)	63.52	cd	d
07	Kainaliu (Mauka)	64.13	d	d

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	16.465	7.54**
Trees within loc. (Error A)	20	2.184	
Harvest Dates	2	1.881	2.00
Loc. X Dates	38	1.338	1.42
Error B	40	0.939	

Table 45. -- Analysis of variance of combined locations for shell length (1/64th inch) of Macadamia integrifolia var. 'Keauhou'

Grand Mean = 61.60

No.	Location	Mean	Duncan's Multiple Range 5%	Duncan's Multiple Range 1%
19	Waiakea Exp. Fm.	58.10	a	a
10	Kau (Hawaii Orchards)	59.51	ab	ab
14	Kolo (Makai)	60.21	bc	abc
18	Malama Ki Exp. Fm.	60.25	bc	abc
06	Honomalino	60.45	bcd	abcd
02	Haiku (Taketa)	60.84	bcde	bcde
13	Kohala (Bond)	61.17	bcdef	bcdef
04	Honakaa (Makai)	61.31	bcdefg	bcdef
20	Waimanalo Exp. Fm.	61.34	bcdefg	bcdef
17	Kurtistown	61.57	cdefg	bcdef
09	Kalopa (Ferreira)	61.88	cdefgh	bcdef
03	Haleakala Exp. Fm.	61.94	cdefgh	bcdef
08	Kainaliu (Makai)	62.22	defgh	cdef
16	Kona Branch Sta.	62.23	defgh	cdef
12	Keopuka (Fukunaga)	62.64	efgh	cdef
01	Captain Cook	62.82	fgh	cdef
05	Honakaa (Mauka)	63.11	fgh	def
07	Kainaliu (Mauka)	63.15	gh	ef
15	Kolo (Mauka)	63.56	h	f
11	Keaau (Royal Haw.)	63.67	h	f

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	12.311	6.33**
Trees within loc. (Error A)	20	1.946	
Harvest Dates	2	1.405	1.78
Loc. X Dates	38	1.362	1.73
Error B	40	0.789	

Table 46. -- Analysis of variance of combined locations for shell thickness at the base (1/64th inch) of *Macadamia integrifolia* var. 'Keauhou'

Grand Mean = 9.72

No.	Location	Mean	Duncan's Multiple Range 5%	Duncan's Multiple Range 1%
02	Haiku (Taketa)	8.31	a	a
16	Kona Branch Sta.	8.58	ab	ab
03	Haleakala Exp. Fm.	8.62	abc	ab
10	Kau (Hawaii Orchards)	8.75	abcd	abc
01	Captain Cook	8.85	abcd	abc
13	Kohala (Bond)	9.23	bcde	abcd
19	Waiakea Exp. Fm.	9.27	bcde	bcd
17	Kurtistown	9.29	cdef	bcd
04	Honakaa (Makai)	9.40	def	bcde
09	Kalopa (Ferreira)	9.63	efg	cde
07	Kainaliu (Mauka)	9.64	efg	cde
05	Honakaa (Mauka)	9.65	efg	cde
08	Kainaliu (Makai)	9.97	fg	def
12	Keopuka (Fukunaga)	10.10	g	def
06	Honomalino	10.27	gh	efg
20	Waimanalo Exp. Fm.	10.31	gh	efg
18	Malama Ki Exp. Fm.	10.83	hi	fgh
11	Keaau (Royal Haw.)	10.86	hi	fgh
15	Kolo (Mauka)	11.18	ij	gh
14	Kolo (Makai)	11.63	j	h

No.	Harvest Date	Mean	Duncan's Multiple Range 5%	Duncan's Multiple Range 1%
2	Oct.	9.48		a
3	Nov.	9.75	a	ab
1	Sept.	9.92	a	b

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	5.079	19.38**
Trees within loc. (Error A)	20	0.262	
Harvest Dates	2	1.934	9.62**
Loc. X Dates	38	0.360	1.79*
Error B	40	0.201	

Table 47. -- Analysis of variance of combined locations for shell thickness at the side (1/64th inch) of *Macadamia integrifolia* var. 'Keauhou'

Grand Mean = 6.52

No.	Location	Mean	Duncan's Multiple Range 5%	1%
02	Haiku (Taketa)	5.59	a	a
03	Haleakala Exp. Fm.	5.73	ab	ab
16	Kona Branch Sta.	5.96	bc	abc
13	Kohala (Bond)	5.99	bc	abc
10	Kau (Hawaii Orchards)	6.00	bc	abc
17	Kurtistown	6.15	cd	bc
19	Waiakea Exp. Fm.	6.16	cd	bc
04	Honakaa (Makai)	6.22	cd	bcd
01	Captain Cook	6.24	cd	cd
09	Kalopa (Ferreira)	6.31	cd	cd
05	Honakaa (Mauka)	6.33	cd	cd
07	Kainaliu (Mauka)	6.44	de	cde
08	Kainaliu (Makai)	6.67	ef	def
12	Keopuka (Fukunaga)	6.68	ef	def
20	Waimanalo Exp. Fm.	6.88	f	efg
11	Keaau (Royal Haw.)	6.95	fg	fg
06	Honomalino	7.25	gh	g
15	Kolo (Mauka)	7.32	h	g
18	Malama Ki Exp. Fm.	7.35	h	g
14	Kolo (Makai)	8.12	i	h

No.	Harvest Date	Mean	Duncan's Multiple Range 5%	1%
1	Sept.	6.35	a	a
2	Oct.	6.44	a	a
3	Nov.	6.76	b	b

Any two means not followed by the same letter are significantly different

Analysis of Variance

Source	d.f.	Mean Square	F
Location	19	2.410	33.47**
Trees within loc. (Error A)	20	0.072	
Harvest Dates	2	1.889	37.78**
Loc. X Dates	38	0.098	1.96*
Error B	40	0.050	

APPENDIX

D

Table 48. -- Homogeneity of variances (sample mean squares), among trees, for shell width, of Macadamia integrifolia var. 'Keauhou'

Harvest Date	Location (orchard reference number)									
	1	2	3	4	5	6	7	8	9	10
Sept.	1.65	1.17	1.23	1.02	1.19	1.99*	1.59	1.70	1.10	1.16
Oct.	1.77*	1.34	1.07	1.48	1.25	1.36	1.58	1.07	1.24	1.56
Nov.	1.83*	1.01	1.21	1.76	1.08	1.05	1.28	1.41	2.12*	1.27
	11	12	13	14	15	16	17	18	19	20
Sept.	1.29	1.30	1.41	1.13	1.05	1.05	1.44	1.17	1.52	1.47
Oct.	2.08*	1.52	1.67	1.38	1.09	1.22	1.04	1.31	1.10	1.26
Nov.	1.29	1.44	1.11	1.04	1.03	1.24	1.07	1.94*	1.98*	1.56

*Significance exceeds the 5% value of F
**Significance exceeds the 1% value of F

Table 49. -- Homogeneity of variances (sample mean squares), among trees, for shell length, of Macadamia integrifolia var. 'Keauhou'

Harvest Date	Location (orchard reference number)									
	1	2	3	4	5	6	7	8	9	10
Sept.	2.07*	1.29	1.02	1.06	1.25	1.83*	1.33	1.75	1.03	1.45
Oct.	1.88*	1.47	1.03	1.57	1.45	1.62	1.45	1.01	1.49	1.74
Nov.	2.04*	1.49	1.08	1.60	1.05	1.16	1.48	1.31	1.46	1.45
	11	12	13	14	15	16	17	18	19	20
Sept.	1.17	1.33	1.54	1.00	1.22	1.25	1.23	1.21	2.40**	1.41
Oct.	1.78*	1.37	1.25	1.29	1.12	1.00	1.17	1.32	1.31	1.12
Nov.	1.25	1.52	1.17	1.07	1.01	1.07	1.12	1.59	2.35**	1.50

*Significance exceeds the 5% value of F
**Significance exceeds the 1% value of F

Table 50. -- Homogeneity of variances (sample mean squares) among trees, for shell thickness at the base, of Macadamia integrifolia var. 'Keauhou'

Harvest Date	Location (orchard reference number)									
	1	2	3	4	5	6	7	8	9	10
Sept.	1.05	1.14	1.27	1.11	1.34	1.04	1.31	1.28	1.12	1.18
Oct.	1.22	1.02	1.02	1.04	1.10	2.24**	1.19	1.72	1.00	1.08
Nov.	2.48**	1.66	1.57	1.18	1.15	1.23	2.09*	1.57	1.45	1.10

Harvest Date	Location (orchard reference number)									
	11	12	13	14	15	16	17	18	19	20
Sept.	1.22	1.21	1.16	1.04	1.16	1.32	1.15	1.27	1.12	1.59
Oct.	1.05	1.03	1.29	1.61	1.35	1.21	1.30	1.26	1.43	1.43
Nov.	1.10	1.15	1.24	1.57	1.51	1.13	1.39	1.25	1.71	2.03*

*Significance exceeds the 5% value of F
**Significance exceeds the 1% value of F

Table 51. -- Homogeneity of variances (sample mean squares) among trees, for shell thickness at the side, of Macadamia integrifolia var. 'Keauhou'

Harvest Date	Location (orchard reference number)									
	1	2	3	4	5	6	7	8	9	10
Sept.	1.20	1.24	1.27	1.16	1.06	1.19	1.01	1.10	1.03	1.51
Oct.	1.21	1.18	1.03	1.06	1.10	1.02	1.13	1.35	1.40	1.12
Nov.	1.87*	1.42	1.12	2.20**	1.39	1.06	2.34**	1.23	1.06	1.14

Harvest Date	Location (orchard reference number)									
	11	12	13	14	15	16	17	18	19	20
Sept.	2.15**	1.82*	1.31	1.37	1.67	1.13	1.66	1.24	1.50	1.13
Oct.	1.09	1.20	1.22	1.41	1.10	1.61	1.03	1.13	1.44	1.02
Nov.	1.33	1.29	1.78*	1.00	1.13	1.04	1.52	2.43**	1.99*	1.37

*Significance exceeds the 5% value of F
**Significance exceeds the 1% value of F

Table 52. -- Homogeneity of variances (error mean squares) among seasons, for shell width, of *Macadamia integrifolia* var. 'Keauhou'

Harvest Date	Location (orchard reference number)									
	1	2	3	4	5	6	7	8	9	10
Sept.	17.197	12.672*	9.185	8.075	18.615	17.857**	11.505	15.643	18.225	15.024*
Oct.	13.575	10.167*	8.241	15.173	21.964	19.446	13.406	13.001*	12.562	9.931
Nov.	16.492**	14.082**	9.766	14.810**	20.133	12.199	15.071*	8.474	15.164	9.032**
Σs^2	47.264	36.921	27.192	38.058	60.712	49.502	39.982	37.118	45.951	33.987
s^2 max./Σs^2	0.3638	0.3814	0.3591	0.3986	0.3617	0.3928	0.3769	0.4214	0.3966	0.4420*
Bartlett's X^2				11.50**				9.21**		7.42*

Harvest Date	Location (orchard reference number)									
	11	12	13	14	15	16	17	18	19	20
Sept.	21.335	10.458**	12.543	16.646**	9.441	9.665	10.392**	13.077	11.906**	11.498
Oct.	29.470**	12.446	15.745*	19.090**	26.607	10.905	17.284*	19.353	11.241	9.349
Nov.	9.944**	18.126**	12.347	25.102	21.671	11.271	13.196**	18.408*	12.414**	10.315
Σs^2	60.749	41.030	40.635	60.838	57.719	31.841	40.872	50.838	35.561	31.162
s^2 max./Σs^2	0.4851**	0.4417*	0.3874	0.4126	0.4609*	0.3424	0.4228	0.3806	0.3490	0.3689
Bartlett's X^2	27.68**	7.90*		4.34	26.22**		6.32*			

*Exceeds the 5% level of probability
**Exceeds the 1% level of probability

Note - astericks by variances indicate that significant differences were found between the 2 trees sampled at the location and harvest date indicated.

Table 53. -- Homogeneity of variances (error mean squares) among seasons, for shell length, of *Macadamia integrifolia* var. 'Keauhou'

Harvest Date	Location (orchard reference number)									
	1	2	3	4	5	6	7	8	9	10
Sept.	14.367	11.344*	7.686	6.787	15.137	12.610**	8.041	14.748	14.781	13.586*
Oct.	12.415	9.127*	6.484	14.963	16.606	15.756	12.309	10.220*	9.683	8.327
Nov.	13.081**	14.928**	9.030	16.723**	15.579	9.591	11.668	7.883*	12.666	9.676*
Σs^2	39.863	35.399	23.200	38.473	47.322	37.957	32.018	32.851	37.130	31.589
s^2 max./Σs^2	0.3604	0.4217	0.3892	0.4346*	0.3509	0.4151	0.3844	0.4489*	0.3980	0.4300
Bartlett's X^2		5.96		21.14**		5.95		9.75**		6.28

Harvest Date	Location (orchard reference number)									
	11	12	13	14	15	16	17	18	19	20
Sept.	17.343	9.722**	10.242	15.108**	9.012	8.053	9.838**	11.846*	9.773	12.275
Oct.	23.576**	10.929	13.073	17.023**	25.663	8.512	16.234*	18.260	8.336	7.821
Nov.	10.454**	16.941**	10.818	22.352	18.588*	9.874	12.775**	14.502*	12.173**	8.577
Σs^2	51.373	37.592	34.133	54.483	53.263	26.439	38.847	44.608	30.282	28.673
s^2 max./Σs^2	0.4589*	0.4506*	0.3830	0.4102	0.4818**	0.3734	0.4178	0.4093	0.4019	0.4281
Bartlett's X^2	15.72**	8.68*		4.01	25.73**		6.07*	4.58	3.55	5.71

*Exceeds the 5% level of probability
**Exceeds the 1% level of probability

Note - astericks by variances indicate that significant differences were found between the 2 trees sampled at the location and harvest date indicated.

Table 54. -- Homogeneity of variances (error mean square) among seasons, for shell base thickness of *Macadamia integrifolia* var. 'Keauhou'

Harvest Date	Location (orchard reference number)									
	1	2	3	4	5	6	7	8	9	10
Sept.	2.765*	1.617	2.390	1.633	2.259**	2.025**	1.857	2.034*	2.704	2.025*
Oct.	2.331	1.641	1.480	2.111	2.133*	2.132**	2.733	1.764	2.260*	1.753
Nov.	2.629	2.296	1.809	2.464**	1.952	2.062	2.639	1.570	1.854	1.686*
Σs^2	7.725	5.554	5.679	6.208	6.344	6.219	7.229	5.368	6.818	5.464
s^2 max./Σs^2	0.3579	0.4133	0.4208	0.3969	0.3560	0.3428	0.3780	0.3789	0.3965	0.3706
Bartlett's X^2		3.97	5.69							

Harvest Date	Location (orchard reference number)									
	11	12	13	14	15	16	17	18	19	20
Sept.	2.522*	2.213**	1.597	3.020**	1.995	1.381*	1.627	2.667	2.099	1.636
Oct.	2.048	1.738	2.097	2.528**	4.160	1.540	2.248	3.431	1.597	2.239
Nov.	2.453	1.873*	1.977	2.431	3.568**	1.697	2.273**	4.131	2.294	2.291**
Σs^2	7.023	5.824	5.671	7.979	9.723	4.618	6.148	10.229	5.990	6.166
s^2 max./Σs^2	0.3591	0.3799	0.3697	0.3784	0.4278	0.3674	0.3697	0.4038	0.3829	0.3715
Bartlett's X^2					13.61*			4.64		

*Exceeds the 5% level of probability
**Exceeds the 1% level of probability

Note - astericks by variances indicate that significant differences were found between the 2 trees sampled at the location and harvest date indicated.

Table 55. -- Homogeneity of variances (error mean squares) among seasons, for shell thickness at the side, of Macadamia integrifolia var. 'Keauhou'

Harvest Date	Location (orchard reference number)									
	1	2	3	4	5	6	7	8	9	10
Sept.	0.809	0.734	0.547	0.647	0.588	0.592**	0.737	0.899	0.791	0.841
Oct.	1.018	0.675	0.631*	0.905	0.764	0.763	0.916	0.846	0.777	0.888
Nov.	1.008	0.907	0.535	0.963	0.884	0.624	1.048	0.813	0.640	0.864
Σs^2	2.835	2.316	1.713	2.515	2.236	1.979	2.701	2.558	2.208	2.593
s^2 max./Σs^2	0.3590	0.3916	0.3683	0.3829	0.3953	0.3855	0.3880	0.3514	0.3582	0.3424
Bartlett's X^2										

Harvest Date	Location (orchard reference number)									
	11	12	13	14	15	16	17	18	19	20
Sept.	0.910*	0.570	0.635*	0.848	0.816*	0.577**	0.732**	1.144	0.713	0.764
Oct.	0.983**	0.785	0.654	0.882**	1.314*	0.513	0.992	1.325	0.838	0.735
Nov.	1.145	0.685	0.681	0.940	1.050**	0.577	1.101**	1.812**	0.902	0.929
Σs^2	3.038	2.040	1.970	2.670	3.180	1.667	2.825	4.281	2.453	2.428
s^2 max./Σs^2	0.3768	0.3848	0.3456	0.3520	0.4132	0.3461	0.3897	0.4232	0.3677	0.3826
Bartlett's X^2					5.49			5.50		

*Exceeds the 5% level of probability
**Exceeds the 1% level of probability

Note - astericks by variances indicate that significant differences were found between the 2 trees sampled at the location and harvest date indicated.

Table 56. -- Homogeneity of variances (error mean squares), among locations, for shell characters of <u>Macadamia</u> <u>integrifolia</u> var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Shell Width	Shell Length	Shell Base Thickness	Shell Side Thickness
1	Captain Cook	52.05	42.90	8.25	1.00
2	Haiku	107.74	90.04	0.67	0.31
3	Haleakala Exp. Fm.	1.47	1.45	1.00	1.21
4	Honakaa (Makai)	60.42	44.00	5.67	0.92
5	Honakaa (Mauka)	9.75	15.70	16.40	0.41
6	Honomalino	111.54	61.72	23.89	4.62
7	Kainaliu (Mauka)	16.81	9.93	3.77	1.11
8	Kainaliu (Makai)	3.46	0.52	3.16	0.04
9	Kalopa	26.53	27.48	5.61	1.33
10	Kau	5.77	4.36	0.37	0.12
11	Keaau	23.05	27.32	0.61	0.82
12	Keopuka	49.96	34.46	3.52	0.19
13	Kohala	25.65	13.22	4.72	0.49
14	Kolo (Makai)	183.24	156.01	2.44	0.91
15	Kolo (Mauka)	38.97	66.14	90.43	14.20
16	Kona Branch Sta.	8.58	4.01	1.37	1.08
17	Kurtistown	163.48	143.60	13.33	13.96
18	Malama Ki Exp. Fm.	7.63	11.57	1.09	5.06
19	Waiakea Exp. Fm.	26.65	28.46	1.00	0.28
20	Waimanalo Exp. Fm.	16.68	6.04	14.13	1.96
Σs^2		939.43	788.93	201.43	50.02
s^2 max./Σs^2		0.1950	0.1977	0.4489**	0.2838*
Adjusted s^2 max./Σs^2				0.2152	0.2314
Bartlett's X^2		22.54	25.83	34.38*	33.83*
Adjusted Bartlett's X^2					

*Exceeds the 5% level of probability
**Exceeds the 1% level of probability

Table 57. -- Homogeneity of variances (error mean squares), among locations, for quality characters of *Macadamia integrifolia* var. 'Keauhou'

Orchard Ref. No.	Grade 1 Kernels (%)	Grade 1 Kernels Angle = Arcsin $\sqrt{\%}$	Grade 2 Kernels (%)	Grade 3 Kernels (%)
1	261.50	108.46	117.17	28.67
2	1.17	24.29	0.67	0.17
3	12.67	25.20	4.17	28.50
4	16.17	11.98	6.17	2.67
5	4.67	5.40	5.17	3.50
6	266.00	94.81	100.17	353.17
7	8.17	5.34	18.67	8.17
8	23.17	38.08	16.17	0.67
9	77.17	34.52	73.17	4.67
10	5.17	0.34	9.50	8.17
11	1.50	0.51	45.17	46.17
12	6.00	8.03	0.50	3.50
13	7.17	16.44	1.17	10.17
14	28.17	11.02	38.17	3.17
15	12.50	14.24	24.50	2.00
16	4.17	4.63	5.17	6.00
17	60.67	37.68	15.17	45.50
18	6.17	6.11	1.17	2.00
19	21.50	40.26	8.17	5.17
20	6.50	23.12	2.67	1.17
Σs^2	830.21	510.46	492.89	563.21
s^2 max./Σs^2	0.3204*	0.2124	0.2377	0.6270**
Adjusted s^2 max./Σs^2	0.2549			0.2198
Bartlett's X^2	38.80**	24.03		
Adjusted Bartlett's X^2	17.39			26.87

*Exceeds the 5% level of probability
**Exceeds the 1% level of probability

Table 58. -- Homogeneity of variances (error mean squares), among locations, for weight characters of Macadamia integrifolia var. 'Keauhou'

Orchard Ref. No.	Orchard Location	Nut Weight	Kernel Weight	Percent Kernel Recovery
1	Captain Cook	0.178	0.058	1.105
2	Haiku	0.225	0.061	0.186
3	Haleakala Exp. Fm.	0.007	0.002	0.072
4	Honakaa (Makai)	0.157	0.021	0.013
5	Honakaa (Mauka)	0.069	0.003	0.741
6	Honomalino	0.345	0.195	15.804
7	Kainaliu (Mauka)	0.053	0.020	1.265
8	Kainaliu (Makai)	0.008	0.004	0.205
9	Kalopa	0.089	0.036	0.914
10	Kau	0.005	0.001	0.013
11	Keaau	0.020	0.001	1.151
12	Keopuka	0.112	0.017	0.042
13	Kohala	0.046	0.006	0.170
14	Kolo (Makai)	0.323	0.060	1.770
15	Kolo (Mauka)	0.136	0.007	5.140
16	Kona Branch Sta.	0.017	0.003	0.245
17	Kurtistown	0.297	0.021	2.070
18	Malama Ki Exp. Fm.	0.017	0.007	0.434
19	Waiakea Exp. Fm.	0.025	0.006	0.284
20	Waimanalo Exp. Fm.	0.016	0.021	2.863
Σs^2		2.145	0.550	34.487
s^2 max./Σs^2		0.1608	0.3545**	0.4582**
Adjusted s^2 max./Σs^2			0.1718	0.2114

*Exceeds the 5% level of probability
**Exceeds the 1% level of probability

Table 59. -- Variance ratios (F) for grade 1 kernels expressed as percent and arcsin transformation

Loc.	Percent		Angle = Arcsin $\sqrt{\%}$	
	Trees	Harvest Dates	Trees	Harvest Dates
1	0.97	0.08	0.91	0.06
2	0.14	1.00	0.04	0.63
3	3.37	7.95	3.17	5.77
4	2.98	2.26	4.59	3.83
5	2.29	0.00	2.27	0.01
6	0.36	0.07	0.34	0.07
7	20.90*	5.53	24.42*	6.45
8	0.35	0.48	0.24	0.47
9	0.01	3.37	0.01	3.47
10	21.81*	43.19*	261.71**	499.30**
11	100.00**	458.11**	118.71**	540.35**
12	25.00*	0.11	24.83*	0.00
13	2.33	0.21	2.34	0.17
14	45.82*	8.54	43.33*	8.17
15	1.08	2.28	1.60	2.78
16	11.56	7.72	13.22	8.90
17	2.64	19.66*	2.01	14.53
18	0.43	14.84	0.16	13.24
19	0.00	0.44	0.01	0.52
20	2.08	2.33	1.98	1.89

*Significance exceeds the 5% point for F
**Significance exceeds the 1% point for F

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